Watershed Assessment of the Middle Powder Subbasin, Montana

Prepared for:

Montana State Office
Bureau of Land Management
Billings, MT

By:

Linda Vance, David Stagliano, and Gregory M. Kudray

Montana Natural Heritage Program
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Executive Summary

We conducted a multi-scale ecological assessment of the 457,454 acres Middle Powder subbasin in Powder River County, Montana, one of ten subbasins in the 13,400 square mile Powder River Basin in Wyoming and Montana. The Powder River Basin in Wyoming and Montana is currently undergoing one of the world's largest coalbed methane developments (Davis and Bramblett 2006), but these ecologically intact grassland and sagebrush communities also support diverse suites of native species, some of which have been identified as potentially declining or vulnerable either locally or regionally (Hiedel et al. 2002).

The Powder River is one of the last undammed large prairie rivers in the United States and provides habitat for the most unique community of benthic invertebrates in Montana (Rehwinkel 1978). No other large prairie system in the ecoregion contains the quality and integrity of its biological communities and habitats. In fact, the Powder River is the reference standard for the Missouri River aquatic classification (Stagliano 2005). Six globally rare to uncommon mayfly species (all are Montana Species of Concern) occur in the Powder River. We found one of these species at all aquatic sampling sites; two of the other species were recorded only at one site. The Powder River is also the primary spawning area for the lower Yellowstone River population of sauger and represents substantial habitat for the sturgeon chub, both Montana Species of Concern. However, sturgeon chub, a former Endangered Species Act candidate, appear to be in decline in the Powder River. In the 1970s, they constituted 5% of all fish sampled in the Powder River. In 2005, neither we nor the USGS (2005) captured a single sturgeon chub within 40 miles of the Wyoming border.

The goal of this study was to provide both landscape-level assessments of watershed health and integrity and site-specific evaluations of riparian and aquatic condition along the Powder River and its tributaries within the 4th-code Middle Powder Hydrologic Unit. This was accomplished using both field sampling and broad-scale GIS analysis.

Our broad-scale GIS assessment examined underlying biological diversity, measured current conditions, and evaluated potential threats. Several key findings emerged from the GIS data analysis:

- Relatively uniform natural diversity across 5th unit HUCs
- Threats are highest in the Powder River floodplain, which is also the most important habitat
- While there are no dams across the Powder River, there is a substantial number of diversions, which has contributed to chronic dewatering conditions
- Roads could threaten aquatic health if not engineered and maintained properly - 66.7% of all tributary streams are within 20 meters of a road
- Grazing is the dominant land use - between 94% and 96% of the land in natural cover is grazed, regardless of ownership (private or public) status
- Native grasslands and shrub steppe dominate; evergreen forests are common, but wetlands rare.
- Noxious weeds, especially leafy spurge, salt cedar and knapweed, have established themselves throughout the Powder River corridor, but are relatively uncommon elsewhere in the subbasin.

The fine-scale rapid assessments plots focused on riparian areas but also evaluated uplands. These surveys generally confirmed the GIS analysis findings that all the study area watersheds were in reasonably good condition, with the lowest levels of disturbance found in the more remote southwestern watershed and the highest levels found in the northeastern watershed near Broadus with its associated agricultural activity. The Powder River cottonwood forest is ecologically significant in its extent. There are also a few tributaries with good condition riparian forests and considerable shrub structure. However, we found that cottonwood

stands are disappearing or becoming decadent through most of the subbasin and regeneration is scarce. Shrub structure important for habitat is absent in most locations.

We identified several management opportunities to support wetland and watershed health:

- The Powder River is unique and important habitat for some Species of Concern. We recommend additional work on the distribution and water chemistry tolerances of the sturgeon chub and the Species of Concern mayflies. We also recommend that these species be included as a component of any biomonitoring approach during CBM development in the Powder River basin.
- As CBM development begins, road-building and equipment movement between sites will greatly facilitate noxious weed transport. Vigilant monitoring and control will be necessary to prevent incursions of noxious weeds into weed-free parts of the watershed.
- Russian olive and salt cedar are established and will degrade future riparian habitat if not controlled now while the infestation is limited. Additionally, the extensive cottonwood forest may virtually disappear if Powder River hydrology is not restored so cottonwoods can establish. The shrub component can return if grazing impacts are limited.
- Because HUCs 060 and 070 have the highest scores on our Composite Watershed Condition index, and a high percentage of public ownership, we recommend they be prioritized for ongoing monitoring and assessment.
- Many permittees already follow good grazing management practices to protect riparian resources. We recommend that these practices be encouraged, coupled with frequent utilization monitoring, and the use of physical barriers where necessary.
- The Powder River reach upstream of Rough Creek (Site 5) was the most biologically intact aquatic site, followed by the Powder River reach at the Wyoming border (Site 1) and Site (2), the Dry Creek reach. We recommend choosing these as future aquatic monitoring sites.

Acknowledgements

We would like to thank the Montana State Office of the Bureau of Land Management (BLM), especially Mike Philbin, for funding assistance for the overall watershed assessment. We would also like to thank Gayle Sitter, Joe Platz and Adam Carl of the Miles City Field Office for support and funding for the Aquatic Program of the Montana Natural Heritage Program.

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Unless otherwise noted, all photographs in the text were taken by MTNHP staff.

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Introduction

The Powder River Basin covers approximately 13,400 square miles in north central Wyoming and southeastern Montana. The Powder River flows in a generally northeasterly direction from its headwaters in Wyoming's Bighorn Mountains through Powder River County in Montana before joining the Little Powder River north of Broadus, Montana. From this confluence, the river continues north until its terminus at the Yellowstone River southwest of Terry, Montana. This report covers the 1,020 square mile Hydrologic Unit known as the Middle Powder River, one of ten subbasins in the larger Powder River Basin (Figure 1).

The study area watersheds (Figure 2) occupy 457,454 acres within the Northwestern Great Plains Steppe Ecological Section (McNab and Avers 1994), an unglaciated, semi-arid, rolling plain underlain by siltstone, shale, and sandstone. In the study area, ponderosa pine (*Pinus ponderosa*) and Rocky Mountain juniper (*Juniperus scopularum*) forests are interspersed with savannah grasslands and sagebrush shrublands at higher elevations. At lower elevations, there is less forest and more agricultural activity. The broad floodplain of the Powder River supports a mix of riparian forests, hayfields, pasture, and some cropland. Except for the Powder River itself, which is a wide perennial river, most of the streams are ephemeral to intermittent. Land ownership is predominantly public (64%), with ownership divided between state trust lands, the Custer National Forest, and the Bureau of Land Management. Within the Powder River corridor, however, the percentage of private ownership is almost 90%. Not surprisingly, the corridor is the site of most of the low intensity residential development, and much of the agricultural use. According to cadastral records, the Bureau of Land Management (BLM) owns 104,440 acres within the study area watersheds. BLM land, like other public land, is primarily leased for grazing.

The Middle Powder subbasin is underlain by coal beds, and has gained substantial attention as a potential locale for coalbed methane (CBM) extraction. In the whole Montana portion of the Powder River Basin, oil and gas industry figures predict an estimated 9,551 methane wells by 2010; the BLM has estimated that figure at 18,000. At the time of this writing, however, legal challenges and delays in developing water quality standards (Total Maximum Daily Loads) for the Powder River have postponed any well drilling in the study area. Nevertheless, the Powder River in the study area is downstream of extensive CBM developments in Wyoming, and concerns have been raised over effects of CBM discharge on Montana resources (Johnson 2006).

The goal of this study was to provide both landscape-level assessments of watershed health and integrity and site-specific evaluations of riparian and aquatic condition along the Powder River and its tributaries within the 4th-code Middle Powder Hydrologic Unit. This was accomplished using both field sampling and broad-scale GIS analysis. To provide a basis for comparison, the larger subbasin was broken into five smaller units for analysis. Four of these units are the 5th code HUCS (i.e. watersheds) that comprise the subbasin. Because land use patterns in the study area were so distinctly different between upland portions of these watersheds and portions lying within the Powder River floodplain, a fifth unit, the Powder River corridor, was delineated for the purposes of analysis. We used indices of watershed integrity developed in earlier watershed assessments (Crowe and Kudray 2003, Vance 2005) as well as some newly developed indices to provide a comprehensive GIS-based evaluation of landscape condition and health across the study area. Field sampling of terrestrial and aquatic sites provided detailed information on the composition and distribution of plant, invertebrate, and fish communities.

Figure 1. Powder River Basin, Wyoming and Montana

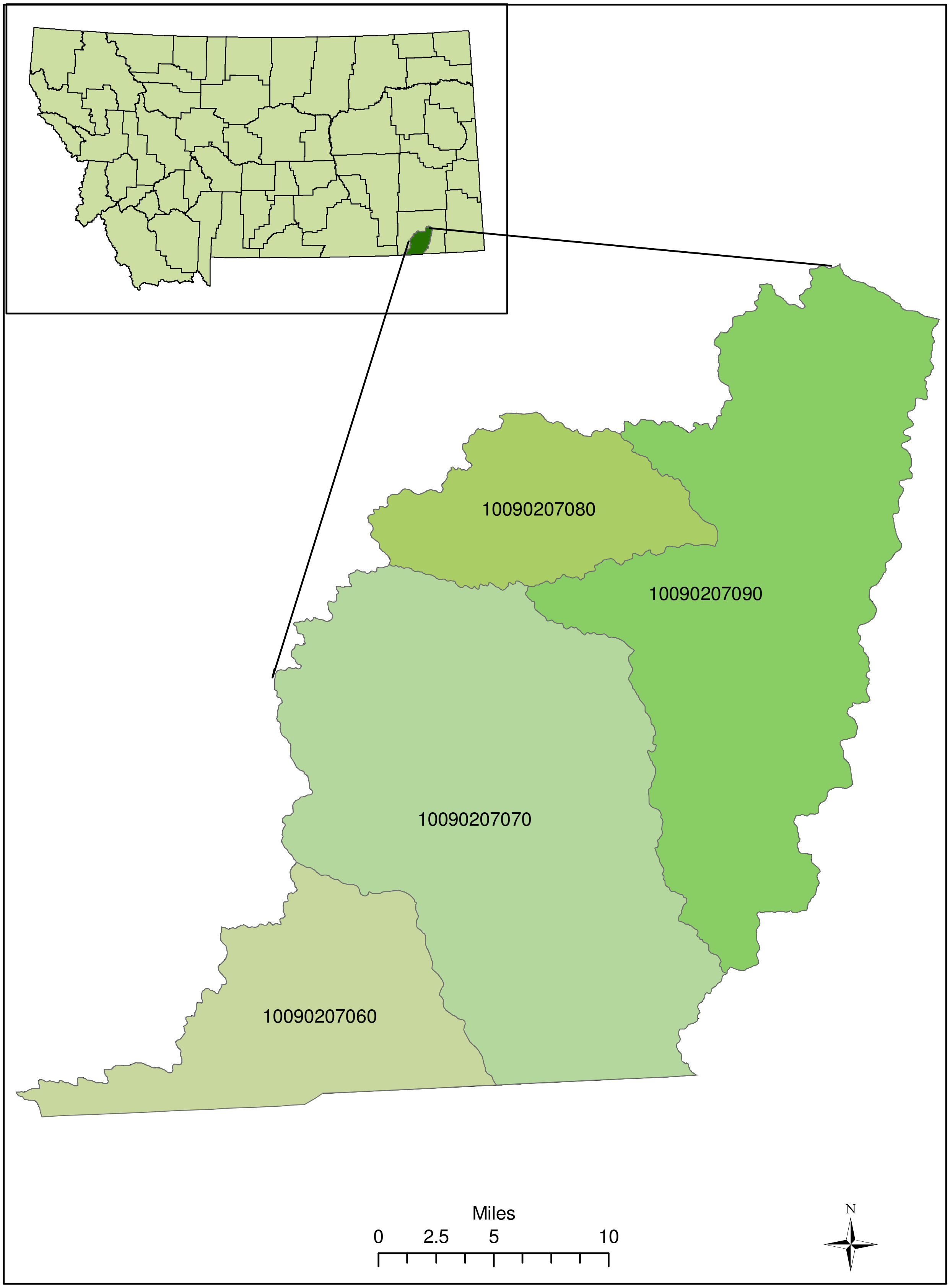


Figure 2. Study area watersheds, Middle Powder subbasin

The Ecological Setting: Climate, Geology, Landform, Soils, and Hydrology

Climate

Within the study area watershed, the climate is typical of the Great Plains Region, with cold winters, warm summers, and seasonally variable precipitation. Temperatures are typically highest in July and lowest in January. In Broadus, the average high temperature in July is 87.54° F, and the average minimum in January is 6.2° F. Comparable averages at Moorhead, near the Wyoming border, are 88.8 ° F and 8.1 ° F. Annual precipitation at Broadus averages 13.51 inches, and total annual average snowfall is 40.9 inches; at Moorhead, this is 12.55 inches and 29.1 inches, respectively (WRCC 2006). In the lower elevations, evaporation is higher than precipitation during summer months (WRCC 2006). Throughout the year, precipitation follows elevation gradients, with lower elevations receiving 10 to 14 inches a year, and higher elevations receiving as much as 20 inches a year. Flash floods occur on occasion in isolated watersheds, and ice-jam floods are sometimes seen in late winter and early spring. The majority of the annual precipitation (75%) occurs during the April to September growing season, with May and June the wettest months. Since 2000, Moorhead has recorded below-average annual precipitation levels in five of six years; Broadus has seen below-average precipitation in four of six years (WRCC 2006)

Geology, landform, and soils

Except for the Quartenary alluvium along the Powder River corridor and at the mouths of larger drainages, the Middle Powder River subbasin bedrock consists almost entirely of Paleocene sandstones of the Fort Union Formation, with a small portion of Eocene Wasatch formation in the extreme southwestern area (Vuke et al. 2001). The Fort Union formation, some 3,500 feet thick, consists of heterogeneous, non-marine shale, siltstone, sandstone and coal beds, as well as several clinker deposits formed by spontaneous ignition and burning of the coal beds and baking of the overlying strata (Parker et al. 1971). The deepest of the three stratiographic members of the Fort Union formation is the Tullock Member; the Lebo Shale Member and the uppermost Tongue River Member overlie this. Most of the coals in the subbasin are in the Tongue River Member. Fractured coal-bed horizons and water-bearing sandstones throughout the Fort Union formation supply groundwater wells, although some deeper, artesian wells extend into the Tullock Member (Parker et al. 1971). The Wasatch formation overlies the Fort Union in the higher elevations near the Wyoming border; it too is primarily sandstone, fine- to medium-grained, interbedded with siltstone and shale but little coal. The Quartenary alluviums of the river corridor are primarily sand, silt and gravel, and are rarely more than 90 feet thick. They contain unconfined aquifers, integrally tied to active river flow, which feed the shallow wells in the valley.

Silt loams and silty clay loams prevail along the tributary valleys, while sandy loams are common throughout the Powder River corridor (Parker et al. 1971) In the uplands, silty loams and clay loams make up the sloping, hilly terrain, often capped with shallow, erosion-resistant shales. Hydric soils are uncommon, occurring in only a small part of the subbasin near the Wyoming border. The landscape is primarily gently rolling dissected plains with occasional steeply sloping badlands and colorful, steep-sided, flat-top buttes (Figure 3).

Hydrology

The Powder River corridor stretches for approximately 43 air miles from the southern boundary of the Middle Powder 4th code HUC at the Wyoming border to its northern edge near Broadus, Montana. Within this corridor, the low-gradient, shallow Powder River flows for nearly 76 river miles, meandering through a broad floodplain that occupies most of the relatively narrow river valley. The hydrography is typical of semi-arid basin and plains watersheds, with severe flooding and drought both occurring on a regular basis. Maximum recorded flow for the Powder River at Moorhead was 31,000 cubic feet per second (cfs) in 1943; minimum flow was 0.01 cfs, recorded several times during 1931-1934. Bankfull

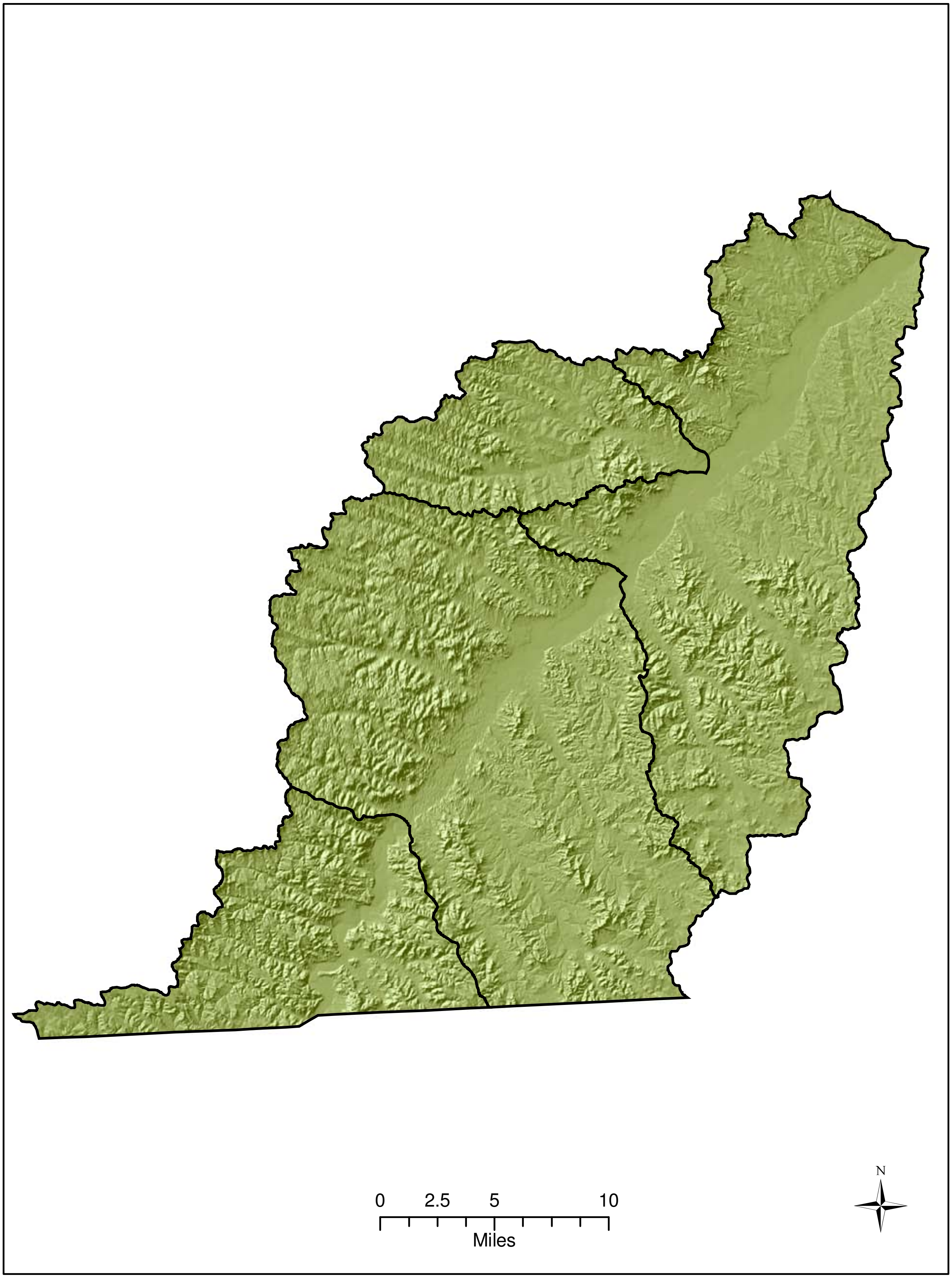


Figure 3. Shaded relief of Middle Powder subbasin

discharge is estimated at 5600 cfs (Martinson and Meade 1983). Table 1 shows peak annual flow since 1923. Within the Middle Powder subbasin, several tributaries flow at least seasonally, but the majority of the tributaries are ephemeral or intermittent, flowing only when extreme rain or snowmelt events occur. In many years, most of the total flow in the tributaries is the result of intense, localized rainstorms (Zelt et al. 1999).

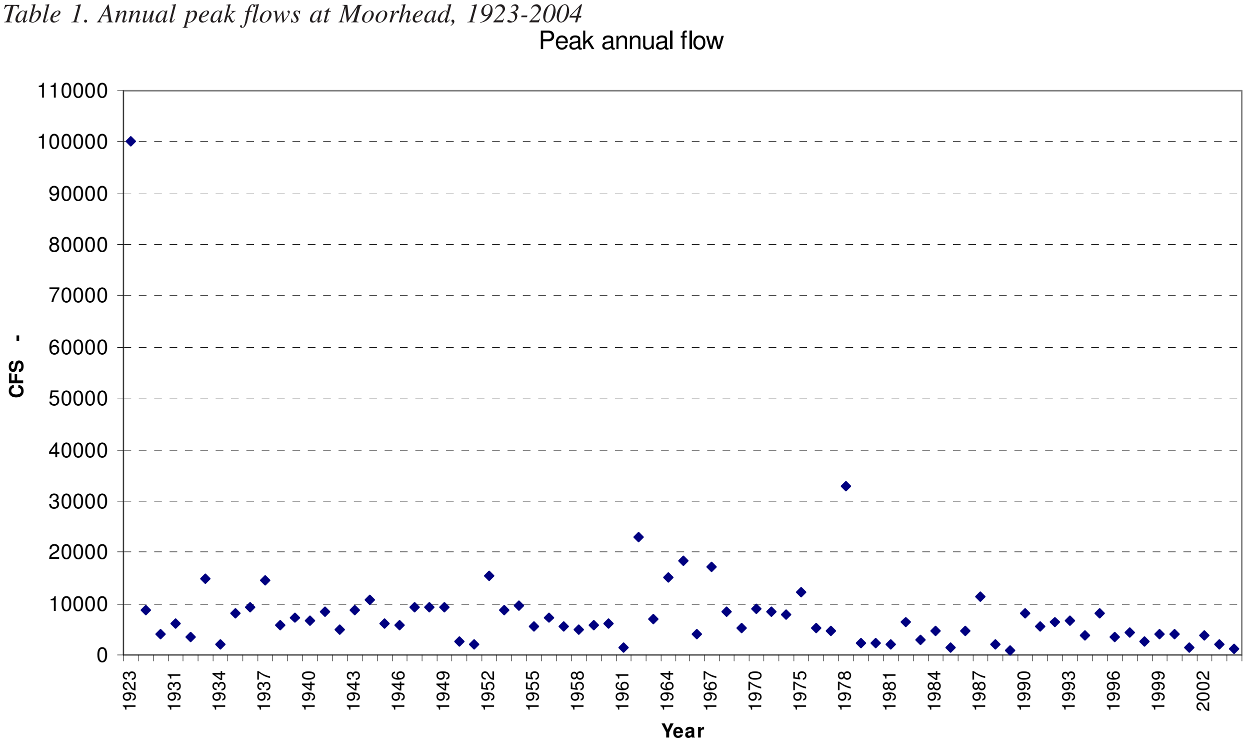
The Powder River channel shifts frequently in response to changes in discharge. A single flood event in 1978 resulted in such extreme bank erosion and cutbank migration that channel width along survey cross-sections increased by an average of 62%, then decreased again in subsequent years as sediments were deposited on low-lying benches (Pizzuto 1994). Analysis of a sixteen year record of channel changes showed that bank erosion exceeds bank deposition in years when annual maximum daily mean discharge is less than 150 square meters per second, while deposition will exceed erosion when annual maximum daily mean discharge is between 60 and 150 square meters per second. Only at discharges of less than 60 square meters per second will deposition and erosion balance out (Pizzuto 1994).

Sediment discharge is high, with between 2 to 3 million metric tons of suspended sediment per year recorded at the USGS gage at Moorhead. Total dissolved solids and salinity levels are also considered high. However, this reach of the Powder River has not been fully assessed for water quality impairment under the Clean Water Act, and therefore is not on any 303(d) list.

Coal and Gas Development

The broad Powder River Basin is believed to have the most abundant coal resources of any coal field in the lower 48 United States (Glass 1997). Coal is found in both Cretaceous and lower Tertiary formations in the basin, but the most frequently developed formations are the Fort Union and Wasatch. Currently, the majority of mines are in the Wyoming part of the basin, where coal is extracted from the Tongue River Member of the Fort Union Formation. Because the coal is sub-bituminous and low in trace elements, sulfur and ash, it is popular for coal-fired power production (Bartos and Ogle 2002). Recently, there has been increased interest in the potential for coalbed methane production in the Powder River Basin. Methane production involves the dewatering of

Table 1. Annual peak flows at Moorhead, 1923-2004



coal to release gas. Typically, wells are constructed by drilling to the top of the coal bed, installing well casing, and reaming of the coal bed, which is then left open to the pump. A submersible pump is lowered into the open coal bed, and the reduction in hydrostatic pressure that is caused by pumping allows the gas to be released. Gas flows to the surface through the space between the well casing and the pump tubing, while the tubing transports the pumped water to the surface (Bartos and Ogle 2002).

Pumping of water from the coal bed reduces the hydraulic head in the aquifer surrounding the seam, creating a cone of depression around the well. Depending on the concentration of wells in a given area, recharge of the aquifer may take anywhere from 2 to 20 years (Wheaton and Metesh 2002). Impacts on water wells in the area also vary. Wells fed by springs or streamflow are unlikely to be drawn down by coalbed methane extraction, unless the spring or stream is itself fed by coal seam aquifers. By contrast, wells drawing directly from coal seams near a methane well may be in its cone of depression, and experience drawdown as a result of pumping (Arthur et al. no date). Whether or not pumping will increase flows to springs, streams or wells remains an open question, and depends on whether the water is discharged to land or holding ponds, or reinjected into the aquifer. Surface discharge will most likely result in the loss of water to evaporation, or at most to recharge of shallow alluvium or coarse soil aquifers (Wheaton and Metesh 2002).

Opinions concerning the amount of recoverable coalbed methane within the Powder River Basin also vary. The USGS estimates 8.24 - 22.42 trillion cubic feet within the entire Basin (USGS 2001), while the Wyoming Oil and Gas Conservation Commission (2002) estimates 31.8 trillion cubic feet within the Wyoming portion of the basin alone. The statewide Environmental Impact Statement for coal bed methane development reported 2.5 trillion cubic feet in the Montana portion of the basin (USDI and State of Montana 2003)

Natural communities

Vegetation

Vegetation surveys conducted during 2000 and 2001 and reviews of previous studies documented a total of 46 native vegetation communities in Powder River County (Heidel et al. 2002). That report and the websites http://www.mtnhp.org and http://www.natureserve.org/explorer/ should be referenced for detailed information on the vegetation communities present in the area. Other than human use, landform is the dominant influence on the vegetation patterns through slope, aspect, and geologic effects on soils. Following is a summary of the most common vegetation types.

Western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), and blue grama (*Bouteloua gracilis*) are the dominant grass species in native valley bottoms that have not been converted to agriculture or planted with crested wheat (*Agropyron cristatum*). Wyoming big sage (*Artemisia tridentata* ssp. *wyomingensis*) is common throughout the area and the Wyoming big sage / western wheatgrass vegetation community is the most widespread shrub community. The nonnative annual bromes, Japanese brome (*Bromus japonicus*) and cheatgrass (*Bromus tectorum*), are common in many valley bottoms.

The riparian zone of the Middle Powder River and larger tributaries is occupied by the plains cottonwood (*Populus deltoides*) / western snowberry (*Symphoricarpos occidentalis*) woodland vegetation community. Smooth brome (*Bromus inermis*) and other nonnative species dominate the herbaceous layer. Smaller riparian areas were the focus of our study and are discussed in detail in the following section.

Grassland sandy soils associated with the abundant sandstone outcrops in the area are mostly vegetated with the needle and thread – threadleaf sedge (*Carex filifolia*) community or the bluebunch wheatgrass (*Pseudoregneria spicata*) – threadleaf sedge community on steeper slopes. Both ponderosa pine (*Pinus ponderosa*) and

Rocky Mountain juniper (*Juniperus scopulorum*) are common within the study area. The ponderosa pine-bluebunch wheatgrass association is found mostly on steep slopes with high gravel or rock content. In the southeastern portion of the study area, Heidel et al. (2002) noted a "complex system of steep ridge slopes covered by a ponderosa pine woodland with some *Juniperus scopulorum* (Rocky Mountain juniper) in the understory," noting that it was "impressive in its extent and complexity, and supports a diverse complex of woodland, steppe and grasslands." The Rocky Mountain juniper – bluebunch wheatgrass communities are well represented on sheltered aspects of dissected terrain. A widespread fire in the southwestern part of the study area in 2000 may have had substantial impacts on this community, as Rocky Mountain juniper is highly flammable when dry, and crowns are almost completely consumed after igniting.

Many slopes are very steep and arid, especially if south facing. These sites typically are sparsely vegetated with the black greasewood (*Sarcobatus vermiculatus*) / bluebunch wheatgrass vegetation community, although we noted that Wyoming big sage was more typically the dominant in this area.

Wildlife and Fish

The Middle Powder subbasin is remote and sparsely populated, with healthy uplands, forests and grasslands that have not been heavily impacted by human land use activities. Consequently, game and non-game wildlife species are abundant. Antelope (*Antelocapra americana*) and mule deer (*Odocoileus hemionus*) range throughout the study area, while elk (*Cervus elaphus*), mountain lion (*Felis concolor*), and black bear (*Ursus americanus*) can be found at higher elevations, especially in the western part of the drainage (USDI and Montana 2003). White-tail deer (*Odocoileus virginianus*) are numerous in the Powder River corridor and along the moister tributaries. Gray Partridge (*Perdix perdix*), pheasant (some), Greater Sage-Grouse (*Centrocercus urophasianus*), Sharp-tail Grouse (*Tympanuchus phasianellus*) and Wild Turkey (*Meleagris gallopavo*) frequent riparian areas and grasslands, while coyote (*Canis latrans*), red fox (*Vulpes vulpans*), and raccoon (*Procyon lotor*) are ubiquitous. Colonies of prairie dogs (*Cynomys ludovicianus*) were observed in the southeastern part of the study area. The extensive cottonwood forest along the Powder River and the green ash draws along the tributaries shelter substantial numbers of birds and bats. The study area is also home to a number of Species of Concern: six bird species, two fish, one mammal, one reptile, six mayflies, and four plants (Table 2).

Although the Powder River is chronically dewatered throughout the study area, the mainstem and its tributaries harbor a fairly representative assemblage of Great Plains fishes. Nineteen of the 21 species found in the drainage are Montana natives (Table 3). More specific descriptions of the aquatic life in the subbasin are found in our discussion of fine-scale assessments later in the text.

Table 2. Species of concern in the Middle Powder subbasin

Common Name	Scientific Name	Global Rank	State Rank	BLM Status
Grasshopper Sparrow	*Ammondramus savannarum*	G5	S2B	
Lark Bunting	*Calamospiza melanocorys*	G5	S3B	
Greater Sage-grouse	*Centrocercus urophasianus*	G4	S3	Sensitive
Sage Thrasher	*Oreoscoptes montanus*	G5	S3B	Sensitive
Brewer's Sparrow	*Spizella breweri*	G5	S2B	Sensitive
Cassin's Kingbird	*Tyrannus vociferans*	G5	S2B	
Sturgeon Chub	*Macrhybopsis gelida*	G3	S2	Sensitive
Sauger	*Sander Canadensis*	G5	S2	Sensitive
Black-tailed Prairie Dog	*Cynomys ludovicanus*	G3G4	S3	Sensitive
Milk Snake	*Lamoroeltis triangulum*	G5	S2	Sensitive
Mayfly	*Homoeoneuria alleni*	G4	S2	
Mayfly	*anepeorus rusticus*	G1G2	S1	
Mayfly	*Macdunnoa nipawinia*	G1G3	S2	
Mayfly	*Raptoheptagenia cruentata*	G4	S2	
Mayfly	*Lachlania saskatchewanensis*	G4	S1	
Sand Mayfly	*Analetris eximia*	G2G4	S3	
Barr's Milkvetch	*Astragalus barrii*	G3	S2S3	Sensitive
Double Bladderpod	*Physaria brassicoides*	G5	S2	Sensitive
New Jersey Tea	*Ceanothus herbaceous*	G5	SH	
Scribner's Panic Grass	*Dichanthelium oligosanthes var. scribnerianum*	G5T5	S1	Sensitive

Table 3. Montana native fishes in the Middle Powder subbasin

Common Name	Scientific Name
Brassy Minnow	*Hybognathus hankinsoni*
Channel Catfish	*Ictalurus punctatus*
Fathead Minnow	*Pimephales promelas*
Flathead Chub	*Platygobio gracilus*
Goldeye	*Hiodon alasoides*
Lake Chub	*Cousesius plumbeus*
Longnose Dace	*Rhinichthrys cataractae*
Longnose Sucker	*Catostomus catostomus*
Plains Minnow	*Hybognathus placitus*
River Carpsucker	*Carpiodes carpio*
Sand Shiner	*Notropis stramineus*
Sauger	*Stizostedion vitreum*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Stonecat	*Notorus flavus*
Sturgeon Chub	*Macrhybopsis gelida*
Western Silvery Minnow	*Hybognathus argyritus*
White Sucker	*Catostomus commersoni*

Methods

Broad-scale Remote Sensing Analysis of Middle Powder Watersheds

The broad-scale assessment was designed to provide a landscape perspective on the natural diversity, current conditions, and potential threats within the study area. We began by separating the study area into component landscape units so that effective comparisons could be made. Based on topography, land cover, and field observations, we selected individual 5th code HUCs, as component units, but delineated a separate unit, the Powder River corridor, for summary statistics and certain analytic operations. The 5th code HUC boundaries were taken from U.S. Geological Survey maps; the Powder River corridor was drawn from digital elevation maps (DEMs) using a heads-up digitizing approach to delineate the broad Holocene floodplain (Figure 4). We used a GIS analysis of existing geographic and statistical data to derive summaries of potential and actual watershed condition, and to compare watershed conditions and threats across the landscape units. The analysis was divided into three parts. The first part assessed the "background" or natural conditions in the watershed by describing potential natural communities, and by using standard diversity indices to evaluate topography and soil-based ecosites. The second part addressed current conditions and disturbances, including land use, ownership patterns, and alterations and impacts to riparian areas. The third part focused on threats to riparian integrity, both actual (e.g. current grazing and agricultural impacts) and potential (noxious weed invasion, agricultural conversion). In each part, indices were used to facilitate comparison between watersheds. This index-based approach follows a method initially developed by the Northeast Region of the National Wetland Inventory Program (Tiner et al. 2000), modified and expanded by the Montana Natural Heritage Program (Vance 2005) to address some of the unique conditions (e.g. grazing impacts, aridity, drought) in western ecosystems. The present work further expands earlier approaches by assigning weights to different land use impacts and geomorphic modifications, building on methodology developed by U.S. Army Corps of Engineers for assessing wetland and riparian function (Hauer et al. 2002). This methodology is explained in greater detail in subsequent sections.

Because National Wetland Inventory photointerpretations for the Powder River Basin were never digitized or turned into hard-copy maps, there was no reliable GIS wetland layer available for analysis. We were able to use GAP maps and National Land Cover Dataset maps to derive some wetland polygons, but the underlying data for these maps is based on 30-meter resolution Landsat images (GAP datasets use these images to produce 90-meter pixels), and so is too coarse to allow identification of wetlands less than 5 acres in size. Consequently, we were unable to assess the number, acreage or types of wetlands affected by land use impacts or other stressors within the study areas. However, our field observations and analyses of soil types indicated that riparian areas are a much more widespread wetland resource than are lentic wetlands within the study area. We believe that the effects of landscape-level stressors on these resources are captured by the broader assessment, and by the stream corridor integrity index in particular.

The geographic data used in the assessment and in calculating the sub-indices were derived as follows:

1. Natural Diversity Index

a) Ecosite Diversity Index

• Using the SSURGO database and 1:24,000 Soils map, create a layer of ecosites and sum acres within each ecosite class.

b) Topographic Diversity

• Create a topography polygon layer with 10-meter elevation intervals from USGS Digital Elevation Maps, and sum acreage in each elevation class.

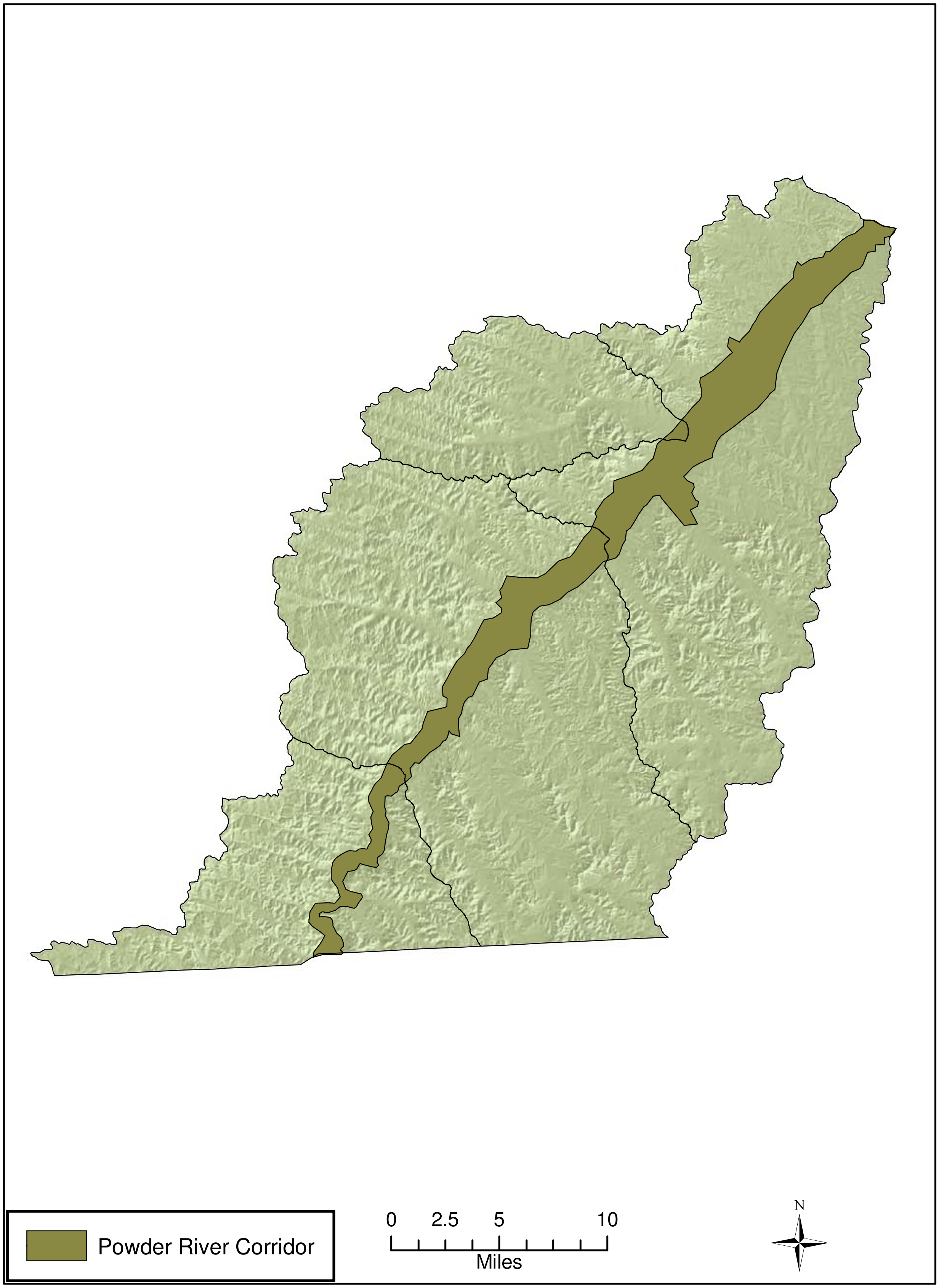


Figure 4. Powder River Corridor

2. Composite Wetland Condition Index

a) Natural Cover Index

• Sum the land cover categories within the watershed boundaries from the USGS National Land Cover Dataset and separate them into human and natural classes;
• Make a public and private grazing lands layer by combining State Trust Lands and BLM lands with those privately held lands listed in the Cadastral database as having grazing as their primary use;
• Overlay the natural land cover class on the public and private grazing lands layer, and sum the acreage within the overlay.

b) Stream Corridor Integrity Index

• Draw a 50- meter buffer on each side of stream segments in the 1:100,000 USGS National Hydrography Dataset streams layer;
• Overlay the buffered stream segments on the National Land Cover Dataset;
• Sum the acreage of land cover categories within the buffered areas.

c) River Corridor Integrity Index

• Draw out the broad Powder River Holocene floodplain from Digital Elevation Maps;
• Overlay the river corridor on the National Land Cover Dataset;
• Sum the acreage of land cover categories within the corridor.

d) Riparian Loss Index

• Create a riparian vegetation layer from GAP 90-meter vegetation data;
• Buffer all tributaries by 45 meters and the Powder River by 90 meters on each side (total of 90 meters and 180 meters, respectively);
• Sum the acreage of riparian vegetation within the buffered areas.

e) Diverted Stream Flow Index

• Create a dams layer and a non-dam diversion layer from the Montana Water Rights layer;
• Overlay the dams and non-dam diversion layers on the USGS National Hydrography Dataset 1:100,000 streams layer;
• Sum the number of dams or non-dam diversions that intersect streams;
• Sum the total number of stream miles.

f) Road Disturbance Index

• Buffer all mapped roads by 20 meters on each side;
• Sum miles of stream and river within the 40 meter road buffer zone.
• Calculate number of road crossings per mile of stream/river length.

3. Composite Riparian Threat Index

a) Riparian Grazing Threat Index

• Select all polygons within the buffered stream corridor layer and the Powder River Corridor layer that are indicated as having natural cover in the National Land Cover Dataset;
• Overlay the public and private grazing lands layer on this natural land cover riparian corridor layer;
• Sum all natural land cover acres within public and private grazing lands layer.

b) Noxious Weeds Threat Index

• Create a layer of Public Lands Survey Sections with known occurrences of noxious weeds;
• Create a layer of susceptible land cover classes (grasses, deciduous forests, woody and herbaceous wetlands) from the National Land Cover Dataset;
• Sum all susceptible land cover wetland acres within sections where noxious weeds are present.

c) Potential Agricultural Threat Index

• Create an agricultural land cover layer from the National Land Cover database;

• Overlay the agricultural land cover layer on the ecosites layer to identify the types of ecosites most susceptible to agricultural conversion;
• Identify the privately owned land currently in non-agricultural use within those ecosites;
• Select all parcels of 40 acres or more and create a potential agricultural lands layer.

Field Data Collection and Assessment

During the summer of 2005, MTNHP ecologists carried out 101 rapid site assessments and 12 complete MTNHP plot-based site assessments in wetland, riparian, and upland terrain throughout the study area (Figure 5). Photos were taken at every site. In all, over 71,000 acres of the study area were assessed. For both wetland and upland plants, our principle floristic references were Dorn (1984) and the Great Plains Flora (1977, 1986). All plant nomenclature follows Kartesz (1999). We analyzed our vegetation data to identify plant associations consistent with the National Vegetation Classification System (NVCS Grossman et al. 1998). This is a hierarchical system combining floristics at the lowest levels (associations and alliances) and physiognomy and climate at the highest levels. Plant associations are defined by the dominant species in the uppermost vegetation layer and any co-dominant species, diagnostic species, or the dominant species of understory vegetation layers.

The MTNHP aquatic ecologist and BLM staff conducted site reconnaissance in early June and established (with GPS points, flagging and site photos) 5 main river sites with one alternative site for the Powder River sampling. During the site reconnaissance, over 18 stream miles were driven or walked on the following streams for potential lotic sampling:

1) Bitter Creek
2) Buffalo Creek
3) Buttermilk Creek
4) Dry Creek
5) Jenkins Creek
6) Maverick Prong of Bloom Creek
7) Rough Creek (north)
8) Rough Creek (south)

However, these streams were consistently dry, and so could not be sampled. Instead, six fish and macroinvertebrate samples, water chemistry and associated habitat data were collected from the Middle Powder River watershed in early July. Five sites were sampled on the mainstem Powder River from the Wyoming border to Broadus, Montana and one site on Bloom Creek at the National Forest border (Figure 6). Overall, 2850 meters (1.8 miles) of the Middle Powder River watershed were evaluated for their aquatic communities.

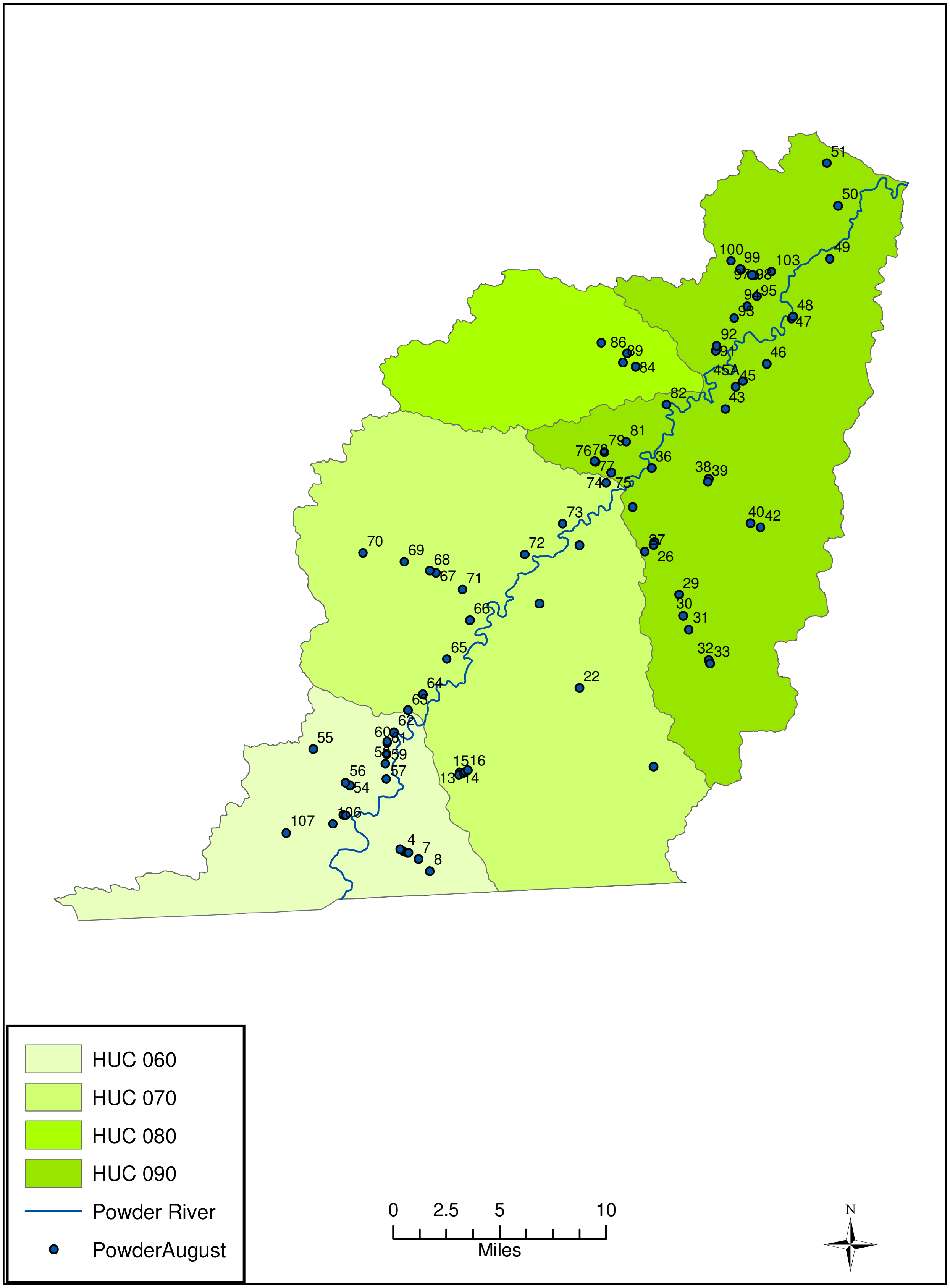


Figure 5. Terrestrial survey sites

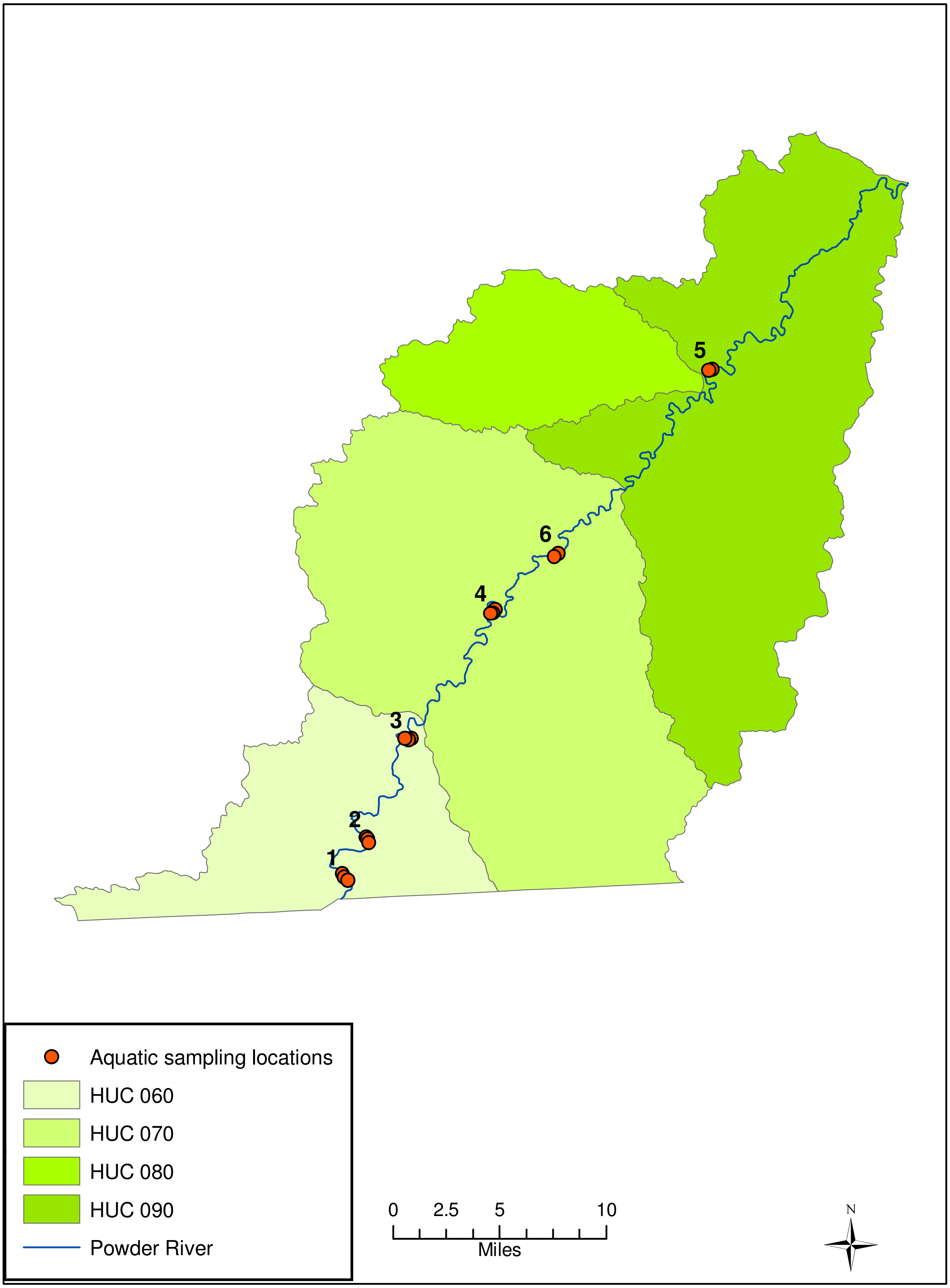


Figure 6. Aquatic survey sites

Results and Discussion

Broad-scale Assessment

Pre-European Settlement Condition

The Powder River region, with its broad grasslands and rich river valleys, once hosted vast herds of buffalo, elk and deer. Assiniboine, Blackfeet, Crow and Gros Ventre tribes were established in the basin, while Cheyenne, Flathead, Nez Perce, Shoshone and Sioux hunted through the area following the seasonal migration of wildlife. Early white explorers, primarily fur traders, began visiting the area in the 1700s, but did not settle. The earliest known account of the natural history of the region comes from Francois Antoine Laroque, who traveled through the Powder and Tongue River basins as part of his "journey of discovery to the Rocky Mountains." Describing the landscape he encountered near the mouth of the Little Powder River on July 27, 1804, Laroque wrote:

"The Powder River is here about ¾ acre in breadth, its water middling deep, but it appears to have risen lately as a quantity of leaves and wood was drifting on it. The points of the river are large with plenty of full grown trees, but no underwood, so that on our arrival we perceived herd of Elk Deers through the woods. There are Beaver dams all along the river. When we arrived here, the plains on the western side of the river were covered with Buffaloes and the bottoms full of Elk and jumping deers & bears, which last are mostly yellow and very fierce. It is amazing how very barren the ground is between this and the less Missouri, nothing can hardly be seen but those Corne de Racquettes (prickly pear cactus). Our horses are nearly starved. There is grass in the woods but none in the plains….The current of the river is very strong and the water so muddy that it is hardly drinkable. The savages say that it is always thus and that is the reason that they call it Powder River; from the quantity of drifting fine sand set in motion by the coast wind which blinds people and dirtys the water. There are very large sand shoals along the river for several acres breadth and length, the bed of the river is likewise sand…and its course North East." (Hazlitt 1934)

Europeans soon established trading posts in the region, and hunting parties began ranging across the plains in pursuit of buffalo. Captain Benjamin Louis Eulalie de Bonnevile established a trading post in Wyoming, in the upper reaches of the Powder River, in 1829. In 1835, Samuel Tullock built Fort VanBuren on the Yellowstone at the mouth of the Rosebud River. Hunting parties traveled down the Powder River, harvesting huge numbers of bear, elk, buffalo, and deer (Roberts 1977), but little exploration occurred until 1859, when the War Department dispatched Captain W.F. Raynolds down the Little Powder River to the mainstem to survey the area. He noted in passing that there was a lack of good pasture and water, and that quicksand was encountered in river crossings (Raynolds 1868). While he does not say so explicitly, the lack of pasture was probably due to increased grazing by buffalo herds, which were already concentrating in this area.

By the mid-1860s, the widespread slaughter of Great Plains bison by buffalo hunters had pushed the last of the great herds into the Powder River Basin, severely depleting the grasslands. Native Americans, following the herds, set up encampments and villages in the area. In the meantime, settlement in other parts of Montana and the West had resulted in bloody clashes between whites and Native peoples. In 1865, a wagon train headed by James Sawyer was set to make its way across Montana to scout a road from Nebraska to Virginia City, where gold had been discovered. The U.S. Army launched a 2,000-man strong military expedition from Fort Connors, near the headwaters of the Powder River, to engage the Indians camped on the Powder and Tongue Rivers. Their goal was ostensibly to distract the tribes' attention from the wagon train as it passed through hostile territory, but orders were specific: the troops were to attack and kill every male over 12 years old to avenge the earlier attacks on white settlers. On the Powder River, at least, the expedition was a complete failure, in part because the buffalo herds had eaten all the grass, and the mules and horses deteriorated from lack of forage. Over 600 mules and horses died during a two day storm in

September of 1865 (Knowles and Knowles 1995). Despite the failure of the Powder River expeditions, increased military action against the Native Americans soon ended their traditional migration and settlement patterns.

Early European Settlement

Displacement of Native Americans made way for European settlement, and land throughout Montana was taken up under the Homestead Law of 1862 and the Desert Land Act of 1877. The Powder River Basin in Montana remained largely unsettled in the first few decades of European homesteading, but cattlemen, many from Texas, began moving their herds onto the open range. The first herds were driven into Montana in 1866; by 1880, the cattle herds had replaced bison in the High Plains (Beach 1989). In the years prior to the final extermination and resettlement of Native Americans in Montana, these cattle herds were free-ranging, and homesteading was largely confined to areas near established towns. After the severe winter of 1886-1887 resulted in disastrous losses to cattle herds, open range grazing in Montana largely ended, and small cattle and sheep ranches were established in the river valleys. The Powder River area was settled in the 1880s and 1890s, and by the early 1900s most of the ranches seen today had been built (Toman 1967).

Current Conditions

Slightly more than 36% of the study area is publicly owned or managed (Figure 7), with the percentage in the 5th code HUCs ranging from a high of 66% in HUC 060 to a low of 23% in HUC 090. In the Powder River corridor, only 11% of land is publicly owned. Of the publicly owned land, approximately 23% is under BLM administration, 7% is in the Custer National Forest, and 6% is State Trust Land. Federal-owned land parcels average 800 acres, but range from less than 6 acres to more than 37,560 acres. The largest publicly-owned land parcel is the Custer National Forest, in HUC 070. Almost 62% of landcover is grassland or herbaceous, 21.4% is evergreen forest, 9.4% is shrubland, and less than 1% is deciduous forest. Wetlands make up less than 2% of the landcover. Non-grazing agriculture, commercial and residential development account for approximately 5% of the land cover in the subbasin (Figure 8). Both public and private rangelands are used primarily for cattle grazing. Figure 9 shows the extent of land that is listed in cadastral records as having grazing a primary use, or that is or managed by the BLM or state trusts; since most BLM and state lands are leased for grazing, those areas are designated as "Public Grazing" in the map.

The study area encompasses 457,454 acres, of which less than 1% (3,017 acres) are herbaceous wetlands and 1% (4,483 aces) are woody wetlands (this acreage is calculated from the NLCD). Over 88% of woody wetlands and almost 59% of herbaceous wetlands are within the Powder River corridor; in fact, virtually all wetlands identified on NLCD maps are within stream or river corridors. There are 1,028 miles of streams in addition to the 76 mile-long Powder River; while it cannot be determined from maps, our field surveys suggest that most of these streams are seasonal/ intermittent, at least during drought cycles.

Factors and Magnitude of Change

Since Euro-American settlement began, four human uses have had significant impacts on watershed health and integrity in the Middle Powder subbasin: extraction, diversion and impoundment of water; conversion of alluvial floodplains to agriculture; livestock grazing in both the river corridor and uplands, and oil and gas development. Associated impacts such as road-building, and secondary impacts, such as timber cutting, have also altered natural conditions.

Extraction, diversion and impoundment of water

In floodplain rivers like the Middle Powder, the spatial and temporal complexity of climate, hydrology and channel morphology creates a highly diverse mosaic of habitats and communities (Power et al. 1995). Fish, macroinvertebrate, and riparian plant communities are adapted to seasonal and annual shifts in climate, runoff, and channel morphology. However, the floods associated with this complex hydrology are not always compatible with human activities. In the early 1900s, settlers

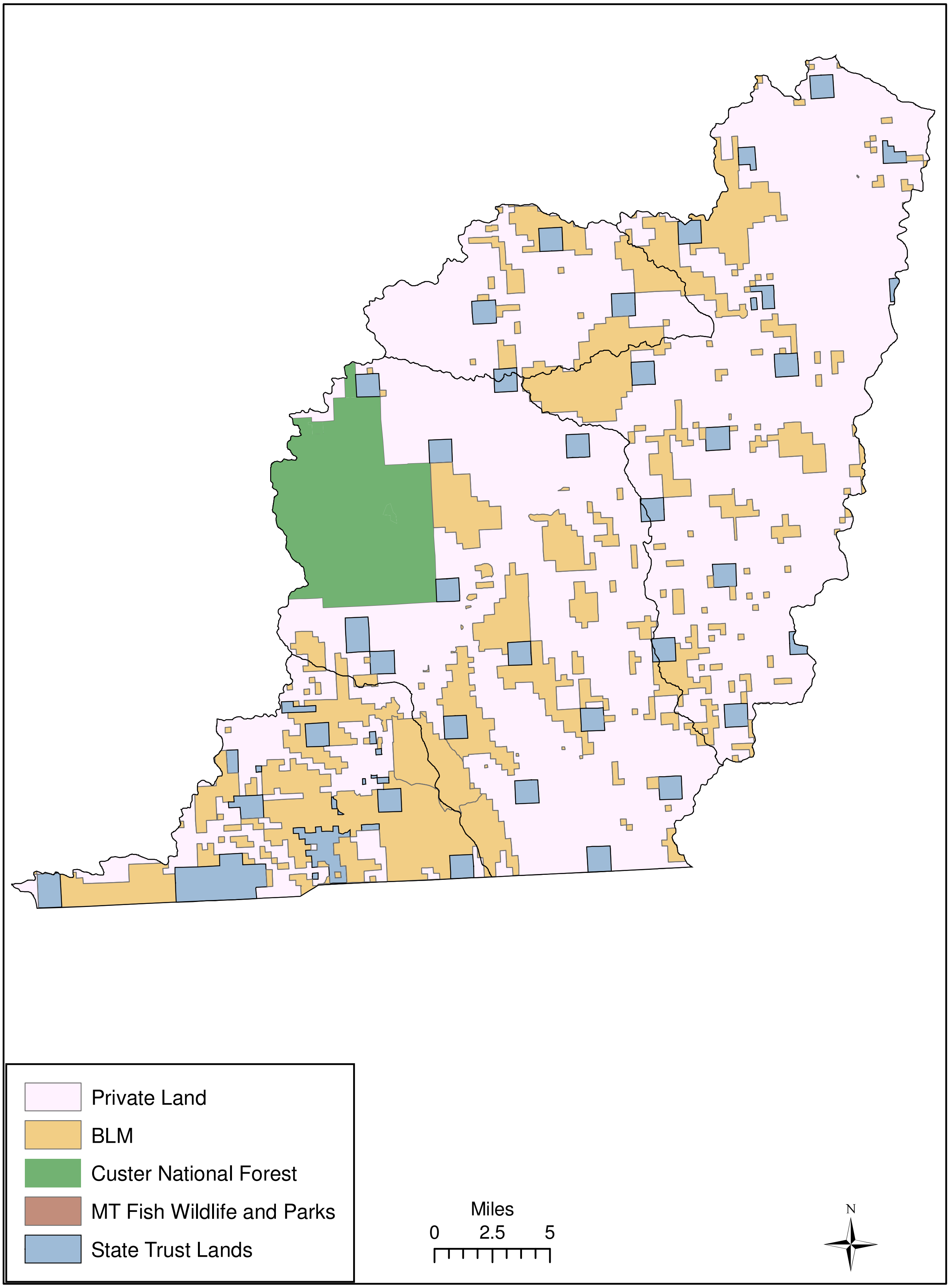


Figure 7. Land ownership and administration

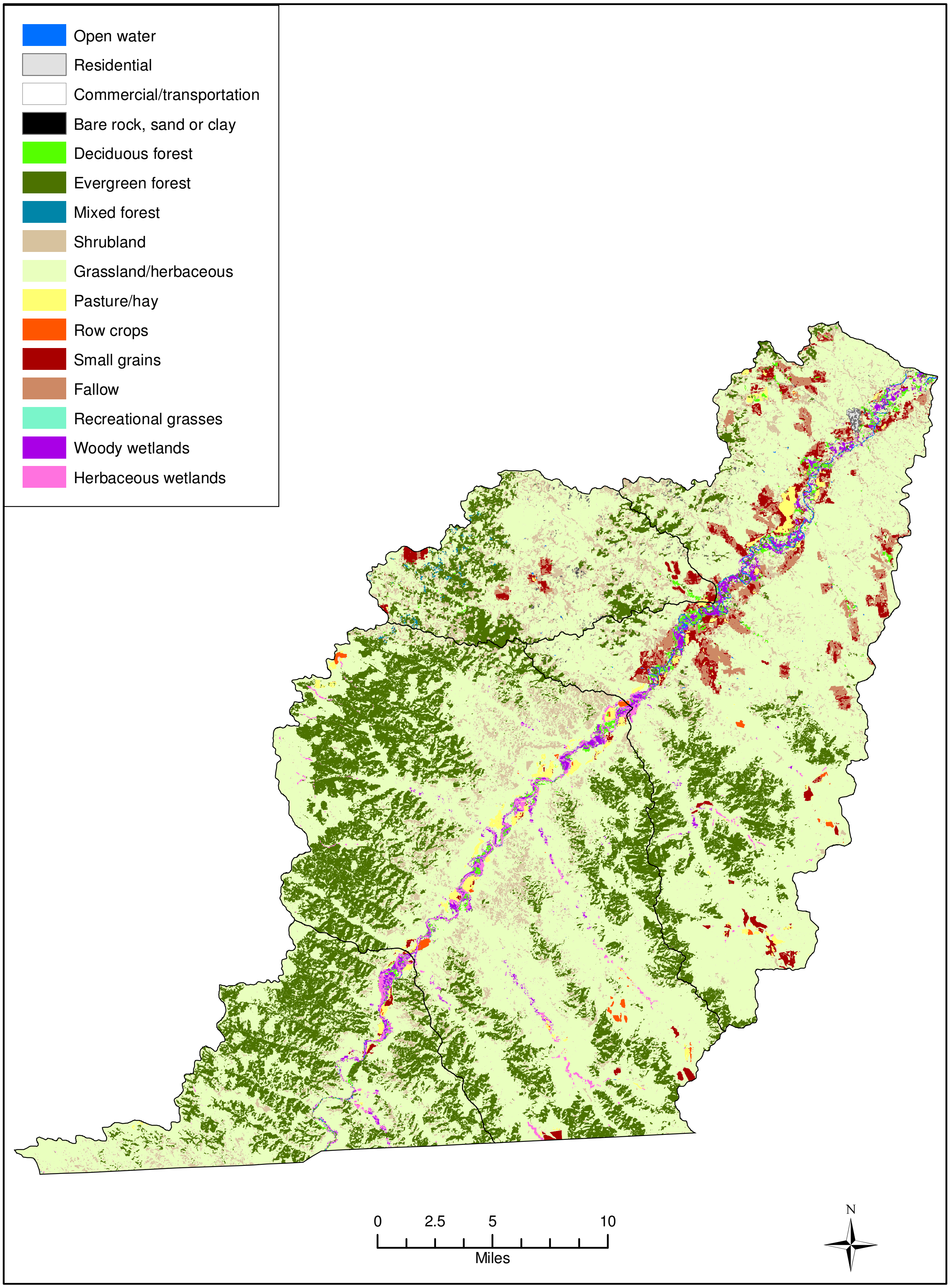


Figure 8. Land cover and land use

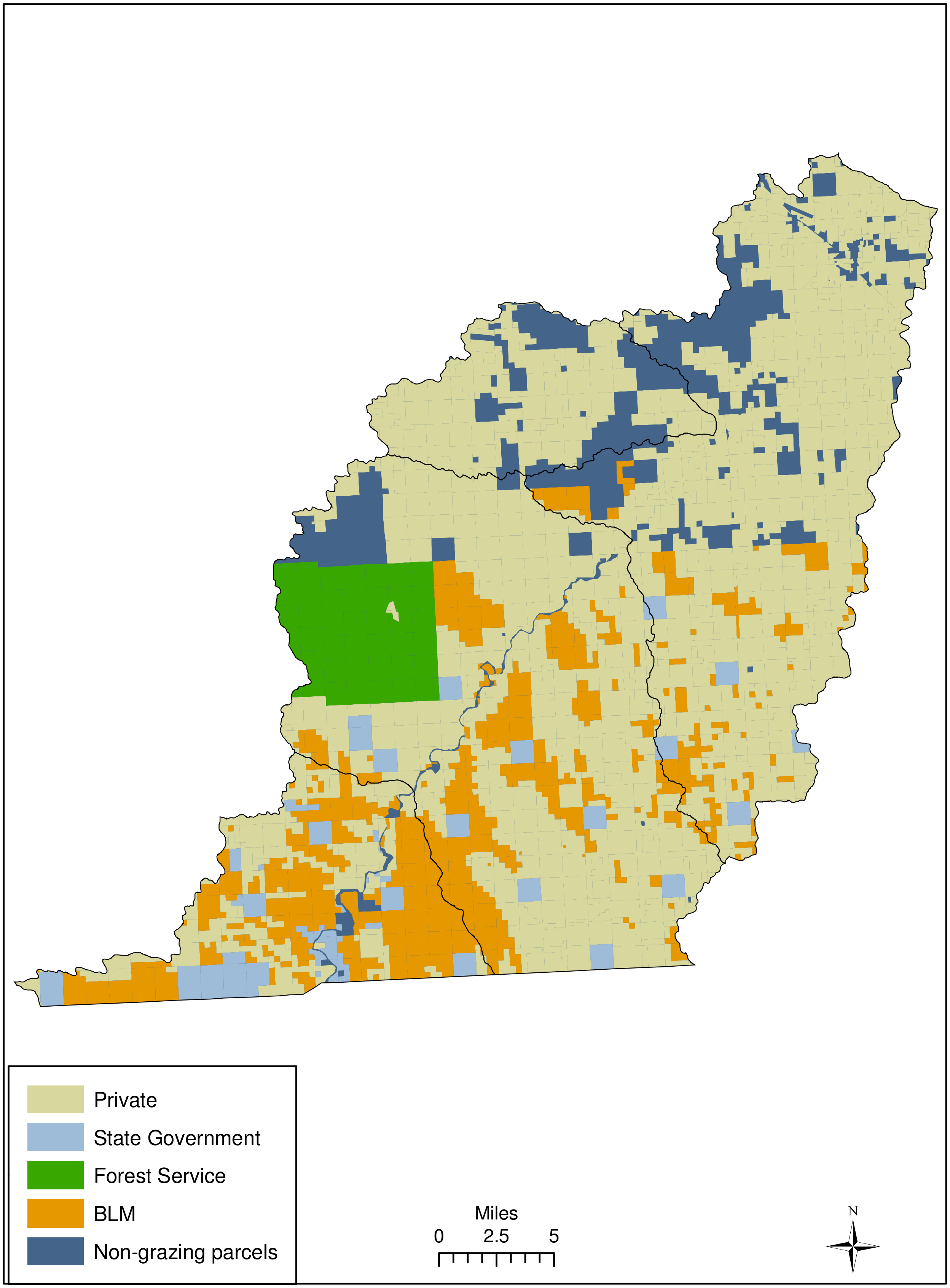


Figure 9. Public and private grazing land

in the Powder River corridor faced frequent floods from spring runoff and from summer rains. The worst of these floods came in late September of 1923, when prolonged rain in the headwaters sent such torrents of water downstream that houses were ruined, thousands of sheep drowned, cattle and horses were stranded, and fences were swept away. Near the town of Broadus, the river was said to extend more than a mile in each direction from its banks (Toman 1967). Estimates by the USGS put the flow rate at Moorhead on September 30, 1923 at 100,000 cfs, over three times the flow during the flood of 1978. Residents and farmers affected by the flood quickly called for construction of a dam, and plans were set in motion to build it. Nevertheless, when opposition arose, particularly from Wyoming, the plans were abandoned (Toman 1967). There is still no large dam on the Powder River. Within the Middle Powder subbasin, however, peak flows have diminished substantially over time. Between 1929, when the gauge at Moorhead was installed, to 1978, the date of the last major flood, annual peak flows exceed 8000 cfs on an average of once every two years. Since 1978, however, peak flow has only exceeded 8000 cfs during 3 of the 26 years of record.

Although there is no dam backing up the Powder River into a reservoir, even smaller dams, diversions and impoundments on streams tend to minimize temporal variability in flows. By eliminating flood peaks, these dams, diversions and impoundments lead to narrowing and firming of channel beds over time, and to the loss of point bars and other bare substrate necessary for successful cottonwood and willow regeneration. In the 4th code Middle Powder HUC, there are currently 714 dams, diversion dams, or headwater gates. Dam density ranges from of a low of 2.5 dams per 100 kilometers of stream corridor in HUC 080 to a high of 4.8 dams per 100 kilometers in HUC 090. HUC 090 has the highest proportion of land in private ownership within the Middle Powder subbasin. In the Powder River corridor, where 89% of the land is in private ownership, dam density is 4.6 dams per 100 kilometers (66 dams), although no dams actually cross the river. Many of the water developments on the Powder River and its tributaries are small diversions for irrigation, so their impact on downstream sediment transport and river floodplain access is not as severe as the impact of a large dam. However, the majority of dams are intended to divert peak flows both during spring runoff and mid-summer thunderstorm events (NRCS 2002), so they do alter the natural hydrology of the system. An analysis of water rights data shows that 551 of these dams and diversions are associated with reservoirs, stock tanks or stock ponds. Total capacity for all subbasin reservoirs is 4,687 acre feet. Nine of the reservoirs are over an acre in size, with the largest covering slightly more than 14 acres.

Conversion of alluvial floodplains to agriculture

Floodplain conversion affects watershed health and integrity in a number of ways: first, it is generally accompanied by water withdrawal for agricultural use; second, it eliminates or impedes regrowth of native vegetation while facilitating invasion by weedy species; and third, erosion from tillage and farm roads contributes to increased sedimentation of streams and rivers (Power et al. 1995).

From an ecological perspective, the floodplain of the Powder River and its tributaries is roughly the extent of the alluvium within the basin. Of the 45,806 acres of land overlying the alluvium within the subbasin, 42,128 acres (92%) are in agricultural or farmstead uses. Ownership is divided between private and public holdings, with 29,210 acres in private hands, 11,191 acres owned by the BLM, 1,636 acres owned by the state of Montana, and 91 acres owned by the Forest Service. Precise acreage for individual uses on alluvial soils cannot be determined from cadastral records, but the NLCD indicates that most of the agricultural use is grazing, with 25,710 acres in grassland, 3,319 acres in crops, hay, or small grains, and 1,311 acres fallowed. Both grazing and irrigated crop production put heavy demands on water, supplied by wells and surface water diversions. Within the entire subbasin, there are 749 wells, of which 237 are in alluvium. Approximately 25% of the wells in alluvium are shallow (30 feet or less in depth), compared to 10% across the subbasin as a whole. Average depth in both alluvial and non-alluvial soils is 250 feet.

Water rights permit irrigation of 23,506 acres within the subbasin, although cadastral records indicate that only 4,579 acres are irrigated. It is likely that much of the land reported in cadastral records as wild hay land (3,672 acres) is also irrigated, as is some of the grazing land. Surface water is generally extracted or diverted with portable pumps. Typically, pumps lift water into feeder ditches or earth-bermed storage basins, and the water is then spread onto the ground through laterals or flooding (NRCS 2002). According to water rights records, only 13 of the irrigation points of use in the subbasin use sprinkler irrigation; most use water spreading (395), flood irrigation (327), or ditch systems (93). Because evaporation in the basin is naturally high (35 inches per year), routinely exceeding precipitation, water spreading and flood irrigation both increase evapotranspiration and contribute to the net water loss in the subbasin (NRCS 2002). The Middle Powder is listed as a chronically dewatered stream by Montana Fish, Wildlife and Parks (MTFWP 2006).

While native vegetation along the Powder River corridor was heavily impacted by buffalo and elk in the decades prior to European settlement, agricultural use has undoubtedly impacted *and* altered the riparian environment. In the semi-arid west, where riparian vegetation is typically dominated by members of the willow and cottonwood family, mid-size rivers like the Powder in the study area should have a corridor marked by moist soils, diverse vegetation, stands of cottonwoods (primarily *Populus deltoides*) arranged in age-specific arcing bands along the floodplain, and willow species (*Salix* spp.) on point bars and channel margins (Scott et al. 1997). This riparian habitat will provide nesting and breeding sites for eagles and heron, cover and forage for deer and turkey, and large woody debris to create pools and backwater habitat within the river itself. In Montana, these riparian forests are used by 134 of the state's 245 recorded bird species during part or all of the year (Partners in Flight 2000). Grazing by bison probably inhibited tree establishment (Knapp et al. 1999) during the period when hunting pressure kept large herds in the Powder River basin, but cottonwood and willows must now contend with flood regimes that are altered through diversions and withdrawals, riparian corridors that are directly manipulated by tillage, irrigation, and fertilization, and grazing by cattle. Both cottonwoods and willows require bare, moist sites for seedling establishment, and protection from disturbance for long-term growth. When flows are insufficient to allow establishment above the bankfull channel, or when floodplains are tilled, planted to crops, or grazed, these species have little chance of success (Scott et al. 1997).

The NLCD shows 3,228 acres of woody wetlands or deciduous forest (7% of total land cover) on the alluvial floodplains. Within the broader Powder River corridor that we delineated for this analysis, woody wetlands and deciduous forest on alluvial and non-alluvial soils account for 6,539 acres, or 15%. Figure 10 shows the location of all the deciduous forests and wetlands mapped by the NLCD in the subbasin; most are within the corridor or the valleys of the larger drainages, but their spatial distribution is fragmented. In our field surveys, we noted that there appears to be very little cottonwood or willow regeneration, that many of the existing cottonwood stands are decadent, and that multiple ages classes are not well represented. The cottonwood forests are also considerably altered, with nonnatives dominating the herbaceous layer and little shrub vegetation structure. Saltcedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*) are establishing themselves along the streambanks. Whether the failure of cottonwood regeneration is attributable to agricultural conversion within the subbasin or hydrological modifications upstream is unclear. Bankful flow in the Middle Powder has been estimated at 5,600 cfs (Martinson and Meade 1983). Generally, bankful flow occurs every 1-3 years, and between 1929 and 1978, that was the case in the Middle Powder. There were only 12 years in which bankful flows did not occur, and only two consecutive two-year periods without a bankful discharge. Since 1978, however, there have been 20 years without a bankful flow, and during the past 10 years, peak discharge has never been above 5600 cfs. Without access to the floodplain, cottonwood seedlings are confined to channel margins, where ice and current can easily displace them.

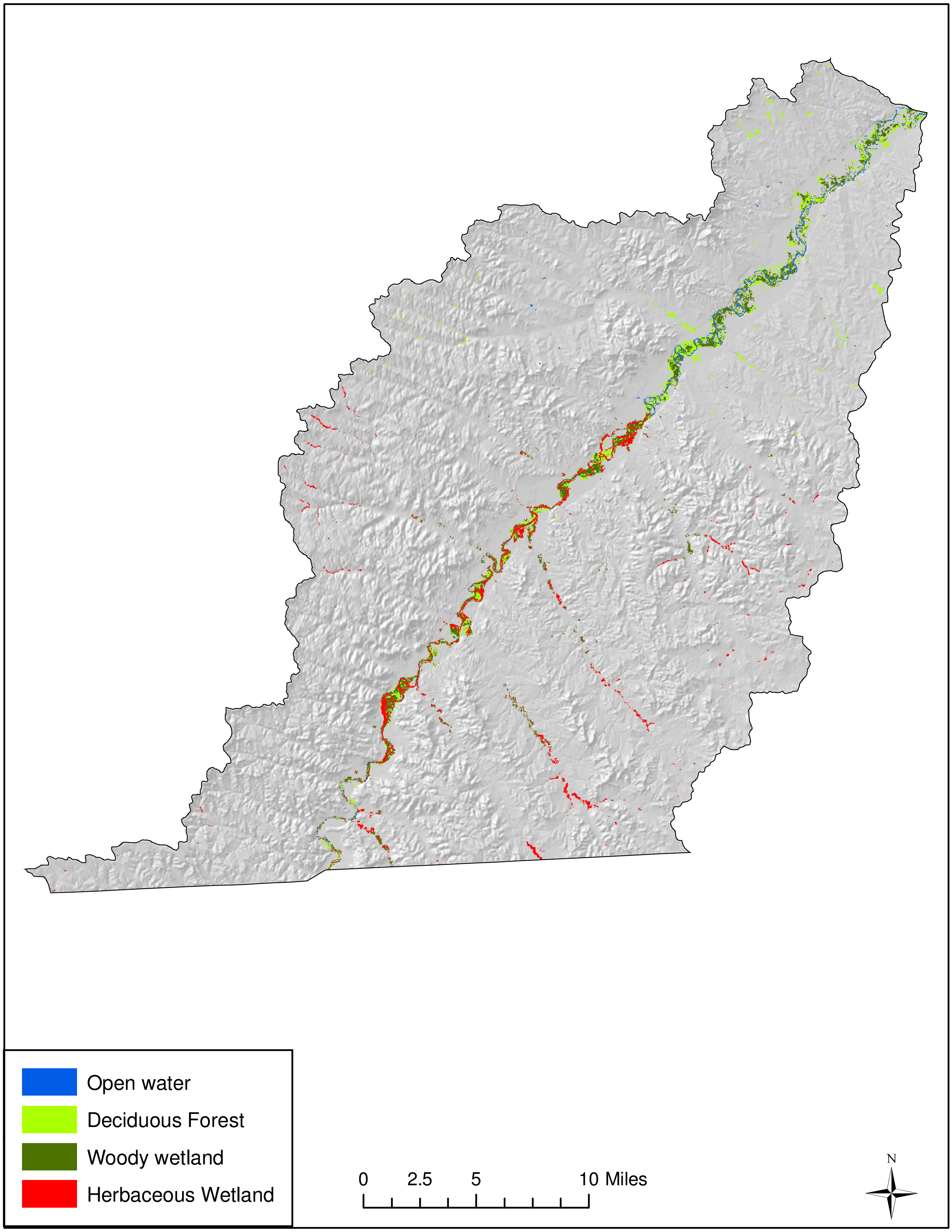


Figure 10. Wetlands and riparian forests

Agricultural conversion also puts aquatic resources at risk through increased erosion and sedimentation. The Powder River as a whole carries a large sediment load, since most of its drainage area is highly erodible sedimentary material (NRCS 2002). Analyses of the Yellowstone River at the Montana/North Dakota border have concluded that only 5% of the water, but 30% of the sediment, originate in the Powder River drainage (Knapton and Bahls 1993). At the gauging station in Moorhead, sediment discharge has been estimated at 2 to 3 tons of suspended sediment per year (Martinson and Meade 1983). Given this, sediment contribution from agricultural practices is probably low within the Middle Powder subbasin. Studies indicate that sediment concentrations decrease between Moorhead and Broadus, suggesting that deposition is a more dominant process than erosion (Martinson and Meade 1983). The same appears to be true for dissolved solids. In general, human activities that displace native vegetation and expose minerals (e.g. mining, agriculture, oil and gas development) make more surface available for weathering and dissolution, and contribute to increased dissolved solids concentrations (Smith et al 1983). Within the Powder River basin, however, studies by USGS hydrologists showed that dissolved solids concentrations decreased from a median of approximately 2400 mg/L at Arvada, Wyoming to about 1250 mg/L at Locate, MT (Zelt et al. 1999). Because most of the suspended sediments and dissolved solids within the basin appear to originate upstream in Wyoming, the Montana Department of Environmental Quality has concluded that it lacks sufficient credible evidence to add the Powder River to the Clean Water Act 303(d) list, although it continues to work on a Total Maximum Daily Load (TMDL) determination for the Powder River.

Livestock grazing

As noted earlier, livestock grazing is the dominant agricultural use in the subbasin. Cattle are the most common grazing animals, although sheep are still present in small numbers. Although the Great Plains ecosystems evolved under grazing pressures from hoofed ungulates, the seasonality and intensity of bison and elk grazing differ from current systems. If not managed appropriately, cattle and sheep grazing can cause soil compaction, nutrient enrichment, vegetation trampling and removal, habitat disturbance, and, depending on the season and intensity of use, reproductive failure for both plants and animals. In riparian areas, grazing can cause stream and river bank destabilization, loss of riparian shade, and increased sediment and nutrient loads in the aquatic ecosystem (George et al. 2002). Stock watering tanks can contribute to dewatering of streams, and concentrate livestock movement and congregation into small areas. In areas with hot summers, like the Middle Powder, cattle are prone to loafing in shady areas, trampling understory vegetation.

Because of ongoing drought, many Montana ranchers reduced herd size in early 2005, and brought in hay to reduce reliance on depleted forage (Boswell 2005). Rains in June led to a “no drought” status in Powder River County by July (NRIS 2005), early enough for vegetation to recover. By the time we visited the subbasin in 2005, most grasslands were in good to very good condition, and grazing pressure appeared to be light. Although we did see sheep and cattle in riparian areas, we did not see widespread evidence of improper grazing or substantial degradation of aquatic resources by livestock. We were told by local ranchers that they had reduced herds substantially, so conditions may not have been “normal” during our visits. However, we did note that in areas with available water, the effects of long-term grazing impacts were often visible in the vegetation composition and patches of bare or eroded soil.

Oil and gas development

Ongoing coal bed methane (CBM) production in Wyoming and planned development in Montana could both have substantial impacts on watershed health and integrity. The BLM’s Reasonable Foreseeable Development (RFD) scenario puts the number of coalbed methane wells in the Middle Powder at 3,167 (USDI and Montana 2003). It is beyond the scope of this report to address all the issues, which have been extensively detailed in both the Montana and Wyoming Environmental Impact Statements (USDI and Montana 2003 and USDI 2003, respectively), and which are currently the subject of a Supplemental EIS being developed by the Montana BLM. However, a brief review of some of the major impacts is warranted.

The level of disturbance associated with exploration, installation and operation of a single CBM well has been estimated at 1, 3.25, and 2 acres respectively (Arthur et al. no date), although this does not include any associated road building, utility corridor expansion, or facilities construction, nor the impacts of housing and transportation for CBM employees. Such activities would have both direct and indirect impacts on wildlife through habitat loss and fragmentation, direct mortality, nest abandonment, noise, and dust. Once in production, CBM wells produce water as a by-product of operation. The total annual CBM water production for the Middle Powder is estimated at 0.55 billion gallons per year under the RFD scenario (Arthur et al. no date). CBM-produced water has a higher Sodium Adsorption Ratio (SAR) than groundwater, which affects soil hydraulic characteristics. SAR measures the concentration of sodium in relation to the summed concentrations of magnesium and calcium. The SAR of water at Moorhead averages 5.2; this could be raised to 6.1 under the RFD scenario (Arthur et al. no date). CBM-produced water is also typically higher in salinity (VanVoast 2003), which is expressed as electrical conductance (EC, in units of dS/m or ¼S/cm) or as total dissolved solids (TDS, in units of mg/L). In anticipation of CBM development, the Montana Department of Environmental Quality (MTDEQ) has established water quality standards for both SAR and salinity in the Powder River Basin (Table 4). However, during water year 2004, real-time EC values recorded at Moorhead were between 902 and 3,960 uS/cm, with a mean value of 2,000 uS/cm, and monthly mean EC values ranged from 1,239 to 3,451 uS/cm. SAR values were between 1 to 8 with the mean being 4.1 (Bobst 2005). On several occasions DEQ standards were exceeded. Given high existing SAR and EC levels in the Powder River, ongoing and future CBM development may have severe environmental and agricultural impacts (USDI and Montana 2003).

Broad-Scale Assessment Indices

In previous watershed assessments (Crowe and Kudray 2003, Vance 2005), the Montana Natural Heritage Program developed a method for broad-scale assessment of wetlands based on a procedure originally developed by the Northeast Region of the U.S. Fish and Wildlife National Wetland Inventory Program (Tiner et al. 2000). We have continued to refine this method, adding new evaluation metrics and refining scoring for land use categories. We believe that these ongoing refinements provide a better baseline for assessment, and more accurately evaluate the stressors found in western watersheds.

We divided the assessment procedures into three parts. The first part uses a Composite Natural Diversity Index, based on underlying soil and elevation factors, to capture the extent and variation of natural conditions within the overall study area and the individual watersheds. In earlier assessments, we were able to evaluate wetland diversity as part of this index; in the Middle Powder, where there are no National Wetland Inventory maps, this part of the assessment could not be performed.

The second part uses four sub-indices of habitat extent and three sub-indices of disturbance to produce the overall Composite Watershed

Table 4. Montana DEQ Water Quality standards, Powder River

	Irrigation Season (March-October)				Non-Irrigation season November-February			
	Mean Monthly EC (uS/cm)	Not to Exceed EC (uS/cm)	Mean Monthly SAR	Not to Exceed SAR	Mean Monthly EC (uS/cm)	Not to Exceed EC (uS/cm)	Mean Monthly SAR	Not to Exceed SAR
Powder River	2000	2500	5	7.5	2500	2500	6.5	9.75
Tributaries	500	500	3	4.5	500	500	5	7.5

Condition Index (CWCI). This index gives a sense of how much natural habitat remains in the study area and watersheds, emphasizing riparian systems and adjacent upland habitat, i.e. buffers. The third part is a Composite Watershed Threat Index, integrating threats from riparian grazing, noxious weeds, and agricultural conversion.

One criticism of indices of biological integrity is that individual characteristics of the system being assessed are blurred by the act of collapsing multiple metrics into a single number (Moyle et al. 1999). To offset this danger, we have chosen to keep the three overall indices distinct from one another. This way, characteristics of each watershed can be compared without significantly diminishing the magnitude of specific disturbances or threats.

Effective buffer widths vary with respect to particular ecological functions (Castelle et al. 1994). Specific effective widths are not known for every function in the unglaciated Great Plains, so we used conservative widths for this assessment. The disturbance indices determine how much riparian areas have been altered since presettlement times. Each index ranges from 0.0 to 1.0. For the habitat indices, values closer to 1.0 indicate greater extent of intact habitat within the watershed. For the disturbance indices, values closer to 1.0 indicate greater disturbance of riparian function. The habitat indices are added together and the disturbance indices are subtracted from this sum to create the CWCI for the watershed.

Composite Natural Diversity Index

Diversity indices are mathematical measurements of community composition. Typically, they are used to assess species diversity, but they can also be used at the landscape level (Rosenzweig 1995). Instead of simple measures of richness, e.g. number of different ecosites or elevation bands, they provide a measure of relative abundance, or distribution of sites, bands, or types across the whole area. We used two common pairs of diversity measures as the starting point for these calculations. The first pair is Shannon's Diversity Index and Equitability Index (Shannon 1948). In the Shannon Index , diversity (H) is calculated as:

$$H= -\Sigma(pi*\ln pi),$$

where pi is the proportion of acres of site or band relative to the total number of acres in the area of interest, and $\ln pi$ is the natural logarithm of this proportion.

Equitability (E) is a value between 0 and 1, and measures the evenness of distribution across an area of interest. It is calculated as:

$$E= H/\ln S,$$

where lnS is the natural log of the total number of sites, bands, or types present.

One shortcoming of the Shannon Diversity Index is that it sometimes over represents rare types, which was not a concern for topography, but did come up when assessing the diversity of ecosites. To offset this, we also calculated Simpson's Diversity Index, which is less sensitive to rare types. In the Simpson Index (Simpson 1949) diversity (D) is calculated as:

$$D= 1/ (\Sigma pi^2)$$

Although equitability is expressed as a number between 0 and 1, calculated numbers for the diversity indices have no such limits. To facilitate comparison, we converted the absolute scores to relative scores by setting the highest diversity and equitability score on a given metric at 1, and taking all others as proportions. For the Ecosite Diversity Index where we used both Shannon's and Simpson's Diversity Index, we combined and averaged the two relative scores. Since there were no rare types in the Topographic Diversity Index calculation, we used only the relative Shannon's Index. We found that Shannon's Equitability represented evenness of types across the study area well, and so we used it as the single measure of evenness.

Ecosite Diversity Index (I_{ED})

The Ecosite Diversity Index characterizes the relative abundance of different ecosite types in individual watersheds relative to the total land area in that watershed. Ecosites reflect the underlying geology, soils, precipitation regime, and landforms, and therefore influence natural community composition, habitat availability, and agricultural potential (USDA NRCS 2003). There are 15 different ecosites in the study area as a whole (Table 5). Across the subbasin as a whole, the two most common ecosite types are the shallow clay 10-14 inch precipitation zone, and the very shallow 15-19 inch precipitation zone. Generally speaking, the shallow clays underlie rangelands on more gentle slopes, while the very shallow sites are found near exposed bedrock.

Based on ecosite types, HUC 090 is the most diverse of the 5th code watersheds, and has the most equitable distribution of types. HUC 080 is the least diverse, and the types represented there are not especially well distributed. However, HUC 080 is also very small compared to the other 5th code watersheds, and includes only a small amount of the Powder River corridor and its ecosites. Table 6 shows individual scores on this metric.

Table 6. Ecosite Diversity Index scores

	Composite Relative Diversity	Shannon Equitability
HUC 060	0.9	0.71
HUC 070	0.98	0.73
HUC 080	0.82	0.62
HUC 090	0.99	0.74
Whole	1	0.75

Topographic Diversity Index (I_{TD})

Like ecosites, topography influences plant community composition and habitat availability for animal populations. Generally, the more topographic diversity within a watershed, the more niche habitat and microhabitat available, and the higher the chance of finding rare types while ensuring broad representation of species found across the watershed as a whole. Elevations in the study area range from 911 to 1,328 meters (2,989 to 4,357 feet) above sea level (Figure 11).

Table 7 shows the scores on this metric, which were so close as to require taking the calculation to three significant digits to identify any difference between HUCs 070 and 090. From the map, it is

Table 5. Ecosite types across study area

Ecosite type	HUC 060	HUC 070	HUC 080	HUC 090
	%	%	%	%
Clayey, 10 to 14 inch Ppt zone, sedimentary plains, east	5.1	9.1	7.8	14.2
Clayey, 15 to 19 inch Ppt zone, sedimentary plains, east	0.0	0.0	0.2	0.1
Claypan, 10 to 14 inch Ppt zone, sedimentary plains, east	0.0	0.2	0.3	0.1
Dense clay, 10 to 14 inch Ppt zone, sedimentary plains, east	0.1	0.6	0.4	0.6
Saline Lowland, 10 to 14 inch Ppt zone, sedimentary plains, east	0.0	0.1	0.0	0.3
Sands, 10 to 14 inch Ppt zone, sedimentary plains, east	1.0	0.9	0.0	2.1
Sandy, 10 to 14 inch Ppt zone, sedimentary plains, east	2.6	2.3	0.2	9.1
Shallow Clay, 10 to 14 inch Ppt zone, sedimentary plains, east	19.8	25.5	45.8	23.8
Shallow, 10 to 14 inch Ppt zone, sedim	4.2	12.5	7.9	14.0
Shallow, 15 to 19 inch Ppt zone, sedimentary plains, east	12.7	6.8	10.5	0.8
Silty, 10 to 14 inch Ppt zone, sedimentary plains, east	3.0	5.3	4.7	9.9
Silty, 15 to 19 inch Ppt zone, sedimentary plains, east	3.9	3.9	2.0	1.9
Silty-Steep, 10 to 14 inch Ppt zone, sedimentary plains, east	0.1	0.4	0.8	1.9
Very shallow, 15 to 19 inch Ppt zone, sedimentary plains, east	39.8	27.9	18.9	20.3
Other	7.6	4.7	0.5	1.1

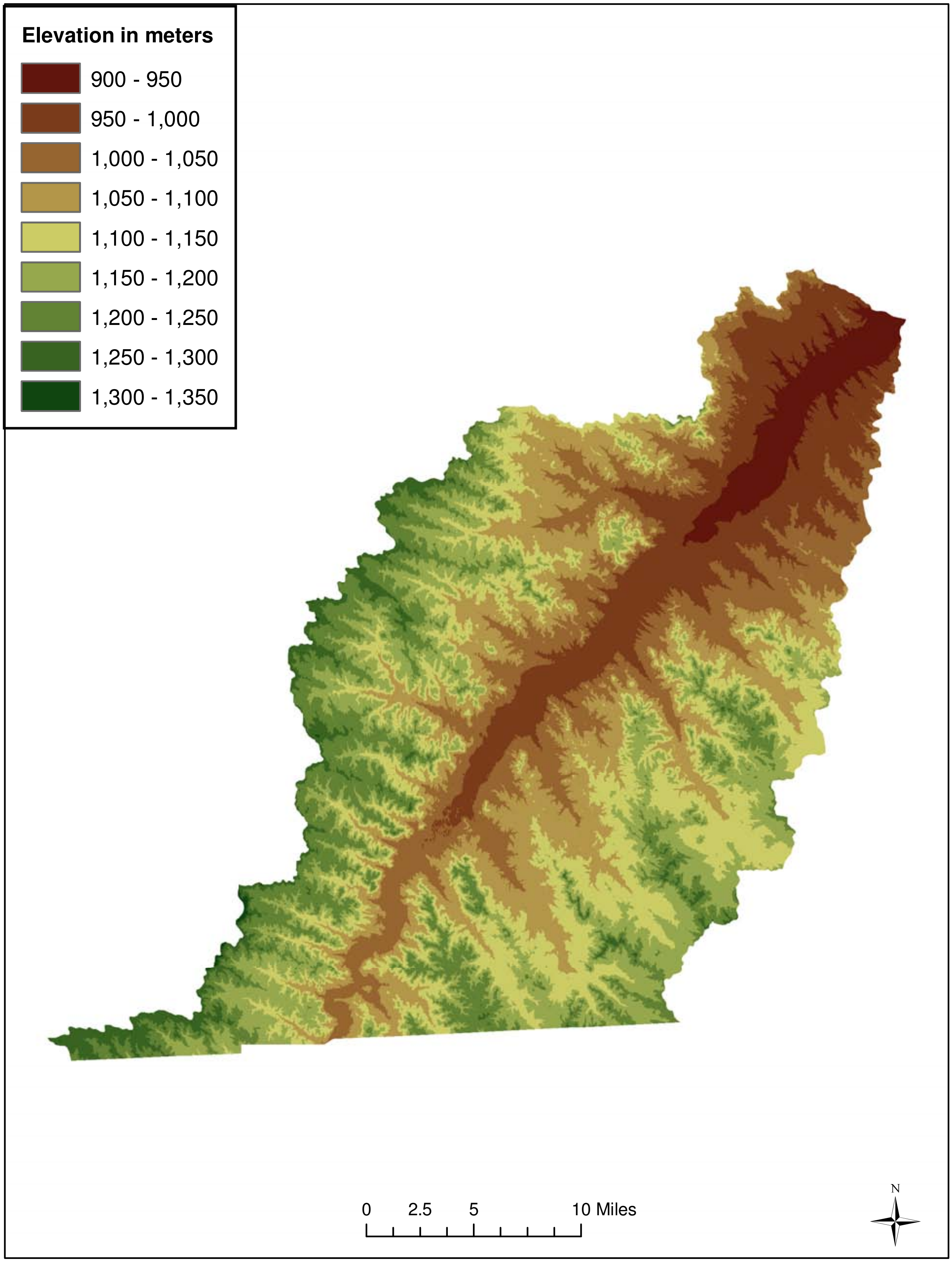


Figure 11. Elevations, Middle Powder subbasin

evident that while certain HUCs have higher elevations than others, these are offset by lower elevations elsewhere. In short, topographic diversity within the subbasin is comparable across all four 5th code watersheds, with no HUC standing out as significantly more diverse. The only notable variation is in equitability, where HUC 90 scores slightly lower than the others, indicating that the distribution of elevation bands is less even across this watershed than others. This, too, is evident on the map.

Table 7. Topographic Diversity Index scores

	Shannon Relative Diversity	Equitability
HUC 060	0.978	0.95
HUC 070	1	0.95
HUC 080	0.991	0.94
HUC 090	0.997	0.92

Composite Natural Diversity Index (CNDI)
We combined the two diversity indices into a Composite Natural Diversity Index. Table 8 shows the scores on this composite metric. Because of the topographic similarity across the subbasin, the CNDI is closely related to the Ecosite Diversity Index, and the watersheds rank in the same order. In short, although there are differences between watersheds based on the factors driving ecosite development (slope, aspect, precipitation, soils), the individual watersheds are relatively similar.

Table 8. Composite Natural Diversity Index scores

	IED	ITD	CDI
HUC 060	0.900	0.978	1.88
HUC 070	0.980	1	1.98
HUC 080	0.820	0.991	1.81
HUC 090	0.990	0.997	1.99

Composite Watershed Condition Index

The Composite Watershed Condition Index is made up of six sub-indices. Three habitat extent indices measure the degree to which the watersheds in the study area retain the natural conditions that are believed to have existed prior to Euro-American settlement: the Natural Cover Index, the Stream Corridor Integrity Index, and the River Corridor Integrity Index. Each of these indices has a score between 0 and 1, with 0 representing the greatest departure from natural conditions, and 1 representing the least departure. These indices are complemented by three disturbance indices that assess the extent of alterations and other disturbances affecting watershed condition: the Riparian Loss Index, the Diverted Stream Flowage Index, and the Road Disturbance Index. Each of these indices also has a score between 0 and 1, with 0 representing the lowest level of disturbance and 1 the highest. To arrive at an overall determination of wetland condition, we summed the three condition sub-indices and then subtracted the summed disturbance sub-indices.

Habitat Extent Indices

Natural Cover Index (I_{NC})
The Natural Cover Index measures the ratio of grassland, forest, shrubland, and wetlands to the total land area in the watershed. Because human activities in watersheds can have far-reaching effects on wetland hydrology, water quality, vegetation, soil development, and nutrient cycling at both the site and watershed scale, more land in natural cover within a watershed can be taken as a positive indicator of overall condition. Inversely, a low score can be interpreted as an indication of the amount of area in a given watershed that is contributing to negative changes in wetland function.

The Natural Cover Index was initially developed for use in the Northeast, where livestock grazing is not as widespread, and consequently it does not account for the impacts of grazing on natural cover. Although rangelands in the western U.S. evolved under grazing regimes, the brief, intense grazing patterns characteristic of bison and elk are not reproduced by cattle (Knapp et al. 1999), and plant community composition can shift radically under continued, season-long grazing, especially if cattle are stocked heavily. The original Natural Cover

Index also does not distinguish between non-natural land use categories; for example, a watershed with 75 % of its land in natural cover and 25% in dry-farmed agriculture would receive the same score as a watershed with 75% of its land in natural cover and 25% in high-intensity residential and commercial development. Therefore, we used a weighting system based on the methodology developed by Hauer et al. (2001, 2002) for field-based landscape assessments, adapting that methodology to the analysis of NLCD data sets. In this system, land uses derived from the NLCD are weighted as follows:

Use	**Weight**
Other	0.5
Open Water	1.0
Low intensity residential	0.3
Commercial, industrial, transportation	0.0
Bare rock, sand or clay	1.0
Deciduous forest	1.0
Evergreen forest	1.0
Mixed forest	1.0
Shrubland	1.0
Grassland or herbaceous	0.7
Pasture or hay	0.6
Row crops	0.2
Small grains	0.2
Fallow	0.5
Urban or recreational grass	0.4
Herbaceous wetlands	1.0
Woody wetlands	1.0

In this weighting system, all grassland polygons are assumed to be grazed. Hauer et al. (2001) assigned weights from 0.2 to 0.7 to grazing depending on intensity, but this was not possible with our remotely-sensed data. Instead, we assumed that spread across all grasslands, grazing could be weighted as "light," or 0.7, since some grasslands would only be grazed sporadically.

The Natural Cover Index is calculated as:

$I_{NC} = A_{LCWt}/A_W$,

where A_{LCWt} = sum of the weighted scores for land cover in acres, and A_W = total area in the subbasin.

For the study area as a whole and the four 5th code HUCs, this calculation would yield the following results (Table 9):

Table 9. Natural Cover Index

	NLCI
Whole	0.79
HUC 060	0.83
HUC 070	0.81
HUC 080	0.80
HUC 090	0.74

On this metric, the subbasin as a whole has a score of 0.79. The watershed most closely approximating a natural land cover state is HUC 060, in the more remote and mountainous southwestern portion of the subbasin, with a score of 0.83. HUC 090, the watershed with the broadest floodplain, most intense settlement, and most developed transportation corridors, is the most altered at 0.74.

Stream Corridor Integrity Index (I_{SCI})

The Stream Corridor Integrity Index measures the amount of natural land cover within a set buffer on either side of all perennial and intermittent streams (but not the Powder River itself, which is evaluated under the River Corridor Integrity Index). It was calculated by creating a 50-meter buffer on each side of the stream segments in the National Hydrography Dataset. (Although this dataset is based on 1:24,000 USGS topographic maps, it has a usable scale of only 1:100,000, and so does not fully represent ephemeral drainages.) This index offers a way to determine whether areas adjacent to streams are contributing more than natural amounts of sediment, runoff and pollution. Croplands and fallow fields will produce higher sedimentation rates than naturally vegetated areas (Wilkin and Hebel 1982), and activities that create impermeable cover (particularly roads and commercial, industrial or residential development) will lead to elevated runoff levels, as well as overland transport of chemical pollutants.

Like the Natural Cover Index, the Stream Corridor Integrity Index as developed by Tiner (2000) is generally a simple ratio of naturally vegetated stream corridor to total stream corridor area, with no allowance made for either grazing impacts or types of non-vegetation cover. Accordingly, we weighted the various land uses as we did in the Natural Cover Index, adjusting our assumptions and the assigned weights slightly to reflect the difference in both use and impacts of land use activities on riparian versus upland systems. We assumed, for example, that grazing pressure would be better characterized as “moderate” than as “light” in riparian grasslands, as cattle are prone to congregate near sites offering shade and water, but that riparian grasslands would be more lush and therefore somewhat more resistant to grazing than more water-stressed uplands. Following Hauer et al. (2002), we therefore gave grasslands in the stream corridor (which we assume are all grazed) a weight of 0.6. Again following the weights assigned by Hauer et al. (2002) for riparian corridors, we changed the weight assigned to Hay or Pasture from a 6 to a 5 to reflect the higher risk of erosion, sedimentation and nutrient enrichment from agricultural activities near a stream. However, we did not change the weights of crop and grain production, which were already low (0.2). The weights we used for individual activities in the calculation of the Stream Corridor Index and the River Corridor Integrity Index were:

Use	**Weight**
Other	0.5
Open Water	1.0
Low intensity residential	0.0
Commercial, industrial, transportation	0.0
Bare rock, sand or clay	1.0
Deciduous forest	1.0
Evergreen forest	1.0
Mixed forest	1.0
Shrubland	1.0
Grassland or herbaceous	0.6
Pasture or hay	0.5
Row crops	0.2
Small grains	0.2
Fallow	0.5
Urban or recreational grass	0.4
Herbaceous wetlands	1.0
Woody wetlands	1.0

We then calculated this index as:

$I_{SCI} = A_{LCWt}/A_{TC,}$

where A_{LCWt} = the sum of the weighted scores for land cover in acres and A_{TC} = total stream corridor area, in acres.

We chose 50 meters as the buffer width on each side of the streams (100 meters total) because most of the tributary corridors are in relatively confined valleys, but we found little difference between scores calculated with 50, 10, and 150 meter buffers. The scores on this metric reflect the same distribution of land uses seen with the Natural Cover Index; the more remote HUC 060 has the highest score, while the more developed HUC 090 has the lowest, with a similar spread (0.10) between the two (Table 10). In all cases, however, the scores came under downward pressure by the amount of grassland within the stream corridor, and the assumption that it was moderately grazed. For the most part, the scores on this metric are high, indicating that there is fairly limited agricultural, commercial or residential development around perennial and intermittent streams.

Table 10. Stream Corridor Integrity Index

	ISCI
HUC 060	0.79
HUC 070	0.73
HUC 080	0.78
HUC 090	0.69

River Corridor Integrity Index (I_{RCI})

The River Corridor Integrity Index measures the amount of natural land cover within the Powder River corridor, defined as the approximate boundaries of the Holocene floodplain. We used digital elevation maps and soils maps to broadly delineate this corridor. In areas where the valley is more confined, the corridor is narrow; in areas where it is broader, the corridor is wider. The area we defined encompasses 43,458 acres.

The index is calculated as:

$I_{RCI} = A_{LCWt}/A_{TC,}$

where A_{LCWt} = the sum of the weighted scores for land cover in acres and A_{TC} = total river corridor area, in acres.

Taken as a discrete unit, the Powder River corridor has an integrity index of 0.66, indicating a high degree of modification along the floodplain and a corresponding high risk of adverse impacts to the riparian and aquatic resources. On a watershed-by-watershed basis, the scores decrease from a high of 0.76 in HUC 060 to a low of 0.65 in HUC 90, reflecting the pattern of increasing land cover modification and use from south to north and upstream to downstream. Only a very small proportion of HUC 080 is within the corridor (152 acres), but that portion has a fairly high percentage of fallow land (18%), thus lowering its score on the I_{RCI}. Individual HUC scores on shown in Table 11.

Table 11. River Corridor Integrity Index

	IRCI
HUC 060	0.76
HUC 070	0.78
HUC 080	0.67
HUC 090	0.65

Habitat Disturbance Indices

Riparian Loss Index (I_{RL})

Land use activities within the stream and river corridor are one measure of the departure from natural conditions; another is the direct loss of riparian vegetation. To calculate riparian loss, we used the GAP vegetation layer, which is more detailed than the National Land Cover Dataset in distinguishing vegetation types, and allows creation of a riparian vegetation layer that includes tree, shrub, and grass/forb riparian types. Because the GAP data has a 90-meter pixel size, we used a 45 meter buffer on each side of tributary streams and a 90 meter buffer on each side of the Powder River, and calculated the acreage within all buffers in each 5th code HUC. We then used ArcGIS Spatial Analyst to calculate the number of riparian vegetation pixels within each HUC's buffer zones, and converted these to acres of riparian vegetation. To be on the conservative side, and recognizing the inaccuracies inherent in GAP maps at this resolution, we calculated that under natural conditions, the riparian buffer zones would include at least 50% riparian vegetation. Any departure from that was held to be a loss. The index was calculated as:

$I_{RL} = 1 – (A_{RVT+} A_{RVPR}/2)/ (0.50 *A_{TR}),$

where A_{RVT} and A_{RVPR} = the acreage of riparian vegetation within the tributary buffer and the acreage of riparian vegetation within the river buffer, respectively, and A_{TR} = the total riparian corridor area, in acres.

Table 12 shows the scores for each HUC; high scores indicate a greater level of disturbance, while low scores equal a lower level. According to this index, three of the four HUCs are comparable in terms of riparian loss; only HUC 070 stands out as having an especially high level.

Table 12. Riparian Loss Index

	IRL
HUC 060	0.57
HUC 070	0.54
HUC 080	0.65
HUC 090	0.58

Diverted Stream Flowage Index (I_{DSF})

As discussed earlier, both dams and surface water diversions change the hydroperiodic flows in a watershed, and deprive riparian communities of the water needed for proper ecological functioning. Dams also trap fine sediments, disrupt normal geomorphological change downstream, and alter the substrate behind them, affecting macroinvertebrate colonization and food chain dynamics (Power et al. 1995). Because many of the water rights records are not accurately georeferenced, but only keyed to Township and Range, we could not produce an accurate layer of free-flowing stream segments versus dammed stream segments. Instead, the diverted stream flowage index is a ratio of the number of dams and surface water diversions to miles of stream. This method, while not completely capturing the impact of diversions and withdrawals, at least gives a basis for comparing the degree of stream alteration between 5th code HUCs. Because scores on this metric are subtracted from the combined scores from the habitat extent indices, we wanted a scoring method that would reflect the ecological consequences of dams. We found this was best obtained by using the formula:

$I_{DSF} = (N_D + N_{Div})/ (L_{TS}/5)$,

Where N_D is the number of dams, N_{Div} is the number of non-dam surface water diversions, and $L_{TS}/5$= length of mapped perennial and intermittent streams and rivers in miles divided by 5. In effect, this is simply the number of dams or diversions per 5 miles of stream/river.

Table 13 shows the scores for the individual HUCs. HUC 090, the most agricultural and developed of the four 5th code HUCs, received he highest score, representing the most dams per 5 miles of river. The other three HUCs were fairly similar to each other.

Table 13. Diverted Stream Flowage Index

	# of dams	IDSF
HUC 060	70	0.31
HUC 070	270	0.30
HUC 080	68	0.31
HUC 090	306	0.39

Road Disturbance Index (I_{RD})

Both improved and unimproved roads compact or cover soil and vegetation, increasing surface runoff. Road rights of way are often colonization sites for exotic species, and unimproved roads contribute to wind and water-borne erosion and sedimentation. Streams and riparian areas in close proximity to roads are more likely to be affected than those at a greater distance (Furniss et al. 1991). In the Powder River subbasin, 68.6% of all tributaries are within 20 meters of a road, and road crossings of streams are common. In the tributaries, especially, these road crossings often go directly through the streambed. Road crossings of the Powder River, by contrast, are limited to bridge sites at either end of the valley.

We focused on tributary streams rather than the Powder River itself in calculating this index because most roads in the Powder River corridor are at the edges of the valley, with the broad floodplain separating them from the river. In calculating the index, we used a 20 meter buffer because roads in the subbasin are so lightly traveled that we felt a 50 meter buffer would exaggerate the impact of the roads.

The Road Disturbance Index is calculated as:

$I_{RD}= ((L_{SR}/L_S) + (RC/ L_S)) / 2$

where LSR = the length of perennial and intermittent streams within 20 meters of a road, in miles, L_S = the total length of perennial and intermittent streams in miles, and RC = the number of road crossings.

In general, these numbers indicate that roads and road crossings pose a potential threat to aquatic integrity throughout the subbasin, with the greatest disturbance occurring in HUC 090 (Table 14). It should be noted, too, that there is probably a use factor that cannot be accounted for in this analysis; use is likely to correspond to intensity of human activity, so that a watershed like HUC 090, with the highest percentage of private ownership and the most human land uses will have roads that are used more frequently than roads in the less-developed HUC 060. However, there is no data available on use, and so this factor was not incorporated. Nor is there any data on culverts draining the road. Culvert design and maintenance can have substantial impacts on aquatic health, especially in areas where roads are minimally maintained (Furniss et al. 1991).

Table 14. Road Disturbance Index

	IRD
HUC 060	0.40
HUC 070	0.49
HUC 080	0.50
HUC 090	0.55

Composite Watershed Condition Index (CWCI)

The Composite Watershed Condition Index is calculated by subtracting the combined disturbance indices from the combined habitat extent indices:

$$CWCI = (I_{NC} + I_{SCI} + I_{RCI)} - (I_{RL} + I_{DSF} + I_{RD})$$

The highest possible score would be 3.00, assuming scores of 1.00 (best) on each of the habitat extent indices and 0.00 (best) on each of the disturbance indices. This score would represent the sort of pristine conditions associated with remote, ungrazed wilderness areas with no history of mining or other human land use. For inhabited areas, scores will obviously be much lower, and can be a negative number when habitat indices are low and disturbance indices are high. In theory, a watershed in a highly urbanized area with multiple disturbances, alterations, and diversions could score as low as –3.00. Most inhabited rural watersheds will score between –1.5 and 1.5 depending on the amount of grazing, agriculture, and development.

The Composite Watershed Condition Index for the Middle Powder 5th code HUCs is shown in Table 15 and in Figure 12. All the 5th code HUCs received positive scores, ranging from a high score of 1.1 in HUC 060 to a low of 0.67 in HUC 090. In general, these scores indicate the presence of mild to moderate impacts on watershed health and integrity. Predictably, impacts are more pronounced in the most inhabited and developed part of the subbasin near Broadus.

Table 15. Composite Watershed Condition Index

	CWCI
HUC 060	1.1
HUC 070	0.99
HUC 080	0.79
HUC 090	0.57

Composite Watershed Threat Index

The Composite Watershed Condition Index is a measure of how much natural conditions have changed across the subbasin, and in individual watersheds, since Euro-American settlement. The Composite Watershed Threat Index, on the other hand, is an attempt to predict which watersheds are most likely to experience continued change and loss of integrity in the future. As is true in other study areas, the rate of change has probably slowed in the past few decades. Road- and dam-building, irrigation ditching and homestead establishment would have been most intense in the first few decades of settlement, and the absence of nearby urban centers has kept residential development to a minimum. In the coming decades, however, activities associated with coalbed methane development may exert pressures on the area. With the specifics of this development as yet unknown, the threats cannot be quantified on a watershed-by-watershed basis. Moreover, given that most of the subbasin is underlain by sub bituminous coal layers, it is difficult to identify factors that would put one watershed more at risk than another. Consequently we merely note here that coalbed methane production poses the most immediate and severe threat to the Middle Powder, and refer the reader to the documentation included in the EIS and forthcoming SEIS.

In this section, we examine three threats to watershed integrity that will continue regardless of CBM development. Two, grazing and noxious weeds, are in the category of cumulative impact threats, i.e. conditions that are ongoing and that tend to have worsening impacts over time. One, agricultural conversion, is more speculative, and residential conversion may emerge as a larger risk as employment opportunities increase. These three threats are by no means an exhaustive list of future possibilities, but they do offer some insight into the susceptibility of the individual watersheds to change.

Riparian Grazing Threat Index (I_{GT})

Cattle grazing can cause soil compaction, nutrient enrichment, vegetation trampling and removal, habitat disturbance, and, depending on the season and intensity of use, reproductive failure for both plants and animals (George et al. 2002). In riparian areas, grazing can cause stream bank destabilization, loss of riparian shade, and increased sediment and nutrient loads. To assess this threat,

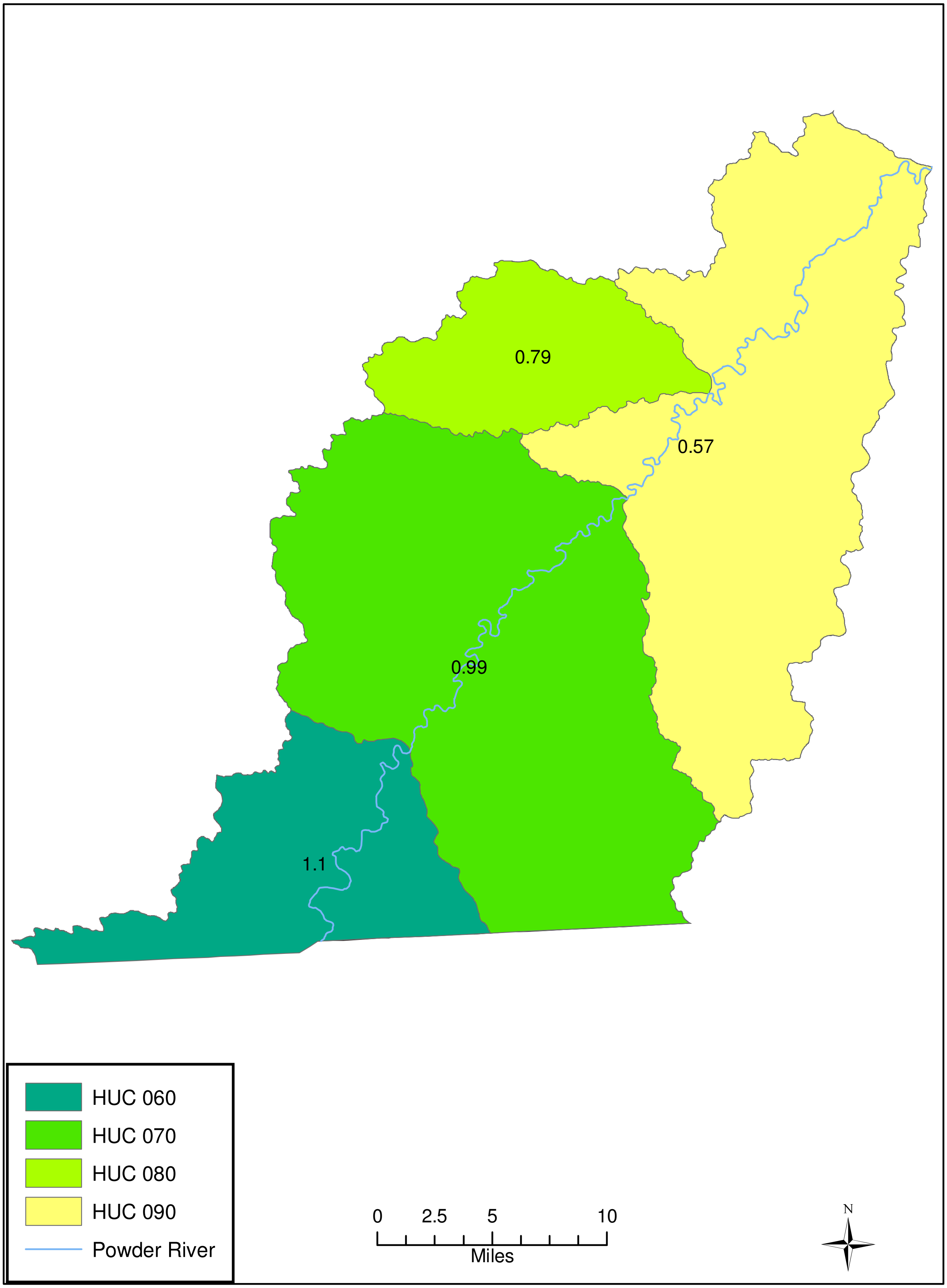


Figure 12. Composite Watershed Condition Index across 5th-code HUCs

we applied the same 180 meter and 90 meter buffers that we used in the calculation of the riparian loss index, but here we measured the percentage of those buffers which were either under public land ownership (assumed to be available for grazing) or were private but listed in cadastral records as having grazing as a primary use. These buffers are narrow to capture the most intense riparian grazing effects (bank collapse, loss of vegetation filtering function, etc.) and to allow a cross-comparison to the Riparian Loss Index.

The Riparian Grazing Threat Index was calculated as:

$\mathbf{I}_{GT} = A_{RG}/A_{RT}$,

where A_{RG} is the area of public and private grazing land in the 90 and 180 meter buffers around tributaries and the Powder River, and A_{RT} is the total buffer area, in acres.

Table 16 has scores for each of the 5th code HUCs. Two caveats should be mentioned. First, the scores represent a potential threat, and not necessarily a realized one. The fact that HUC 060 has the highest score does not mean its riparian areas are in worse condition than any other 5th code HUC but only that it has the highest percentage of riparian grazing land. Management practices and stocking rates will determine actual condition. Second, low scores only indicate potential grazing threats, not impacts that may have already occurred. HUC 080, for example, has the lowest score on the Grazing Threat Index (0.75) and the highest score (0.65) on the Riparian Loss Index. Taken together, these scores indicate that other land use activities (roads, non-grazing agriculture, etc) may exert a greater influence on riparian vegetation than grazing. In short, this index merely represents the percentage of the riparian buffer where grazing may occur, and is simply a flag for management activities.

Table 16. Riparian Grazing Threat Index

	RGTI
HUC 060	0.96
HUC 070	0.90
HUC 080	0.75
HUC 090	0.83

Noxious weeds threat index (I_{NWT})

Russian knapweed (*Centaurea repens*), spotted knapweed (*Centaurea maculosa)*, and leafy spurge (*Euphorbia esula*) are all common throughout the subbasin, especially in and around cultivated fields and riparian areas. All three pose threats to plant and wildlife diversity, aquatic integrity, and agricultural production (Pokorny and Sheley 2003). Plants spread easily during high water flows and along roadways, and establish themselves rapidly on bare or disturbed ground. Spotted knapweed is especially invasive in grasslands dominated by native bunchgrasses.

Noxious weeds pose a threat to both uplands and riparian areas, although displacement of native plants in riparian areas has specific impacts on aquatic health since erosion and sedimentation are increased (Pokorny and Sheley 2003). However, noxious weed presence is reported only on a square mile section basis, and there was no way to distinguish weeds in riparian areas from weeds in uplands at that resolution. Moreover, since over 98% of sections in the subbasin contain at least one stream segment, whether perennial or ephemeral, we felt that any noxious weeds present in a section represented a threat. We therefore calculated this index as:

$I_{NWT} = A_{SCNW}/A_{SC}$,

where A_{SCNW}= the area of susceptible land cover classes (specifically, deciduous forests, grasslands, and woody/herbaceous wetlands) in sections known to have noxious weeds and A_{SC} = the total area of susceptible land cover classes in the watershed.

The scores for each 5th code HUC are shown in Table 17. HUC 070 ranks highest on this metric, with a score of 0.25, while HUC 080 ranks lowest with a score of 0.07. In both cases, the score reflects the concentration of noxious weeds in and around the Power River floodplain (see Figure 13). The low score for HUC 080 is probably more attributable to the small amount of Powder River floodplain included in the watershed boundary than to an inherently weed-free area, while HUC 060's high score is due to the greater proportion of its total area within the floodplain compared to other 5th code HUCs. These scores are generally low, and indicate that noxious weeds are not widespread in the subbasin. However, two cautionary notes are appropriate here. First, this index does not include all noxious weeds, and particularly omits saltcedar, which has not been mapped, but which has high invasive potential. Second, the fact that sections with a noxious weed presence are clustered in and around floodplains is cause for concern, as both human activity and natural flood cycles increase the likelihood the weeds will spread. Third, Russian olive is presently not considered to be a noxious weed but has the potential to significantly alter important riparian habitat over time (Kudray and Cooper 2004)

Table 17. Noxious Weed Threat Index

	INWT
HUC 060	0.25
HUC 070	0.12
HUC 080	0.07
HUC 090	0.19

Potential Agricultural Threat index (I_{PAT})

Livestock production has dominated agricultural enterprise in the Middle Powder subbasin since European-Americans first established a presence in the region, and crop agriculture is largely limited to the production of alfalfa and small grains. However, with ongoing drought, high transportation costs, and increased demand for rural acreage in the event of CBM-related development, we believe there may be some danger of grasslands being converted to crop acreage in the future. The Potential Agricultural Threat Index examines the types of ecosites where non-grazing agriculture is concentrated, and then measures the acres of grasslands, deciduous forests, and herbaceous/woody wetlands on those ecosites that are privately owned and therefore available for conversion. The index is calculated as:

$$IPAT = (A_{SL}PAT/A_{LW}),$$

where A_{SLPAT} = the area of susceptible lands (grasslands, deciduous forests and herbaceous/woody wetlands on privately-owned ecosites typical of agricultural lands), and A_{LW} is the total area of grasslands, deciduous forests and herbaceous/woody wetlands in the watershed.

Table 18 displays the scores for this metric. HUC 060 has the lowest score, while HUC 070 has the highest. These scores can be interpreted as a combination of several interacting factors: the relative frequency of agriculturally-desirable ecosites, the amount of private land in a given HUC, and the amount of land already in agricultural production. Taken as a whole, they suggest that there is still a fairly large amount of private land in the three northern HUCs that could be converted to non-grazing agriculture. Not all of these parcels would be suitable for conversion, of course; issues of access and water still apply. However, this metric provides a preliminary basis for comparing this threat across watersheds.

Table 18. Potential Agricultural Threat Index

	IPAT
HUC 060	0.14
HUC 070	0.37
HUC 080	0.29
HUC 090	0.30

Composite Threat Index (CTI)

The Composite Threat Index is a simple sum of the three sub-indices, with the maximum possible score being 3.0, indicating a high degree of threats:

$$CTI = I_{GT} + I_{NWT} + IPAT$$

Table 19 shows the results for individual watersheds. Overall, these scores are not

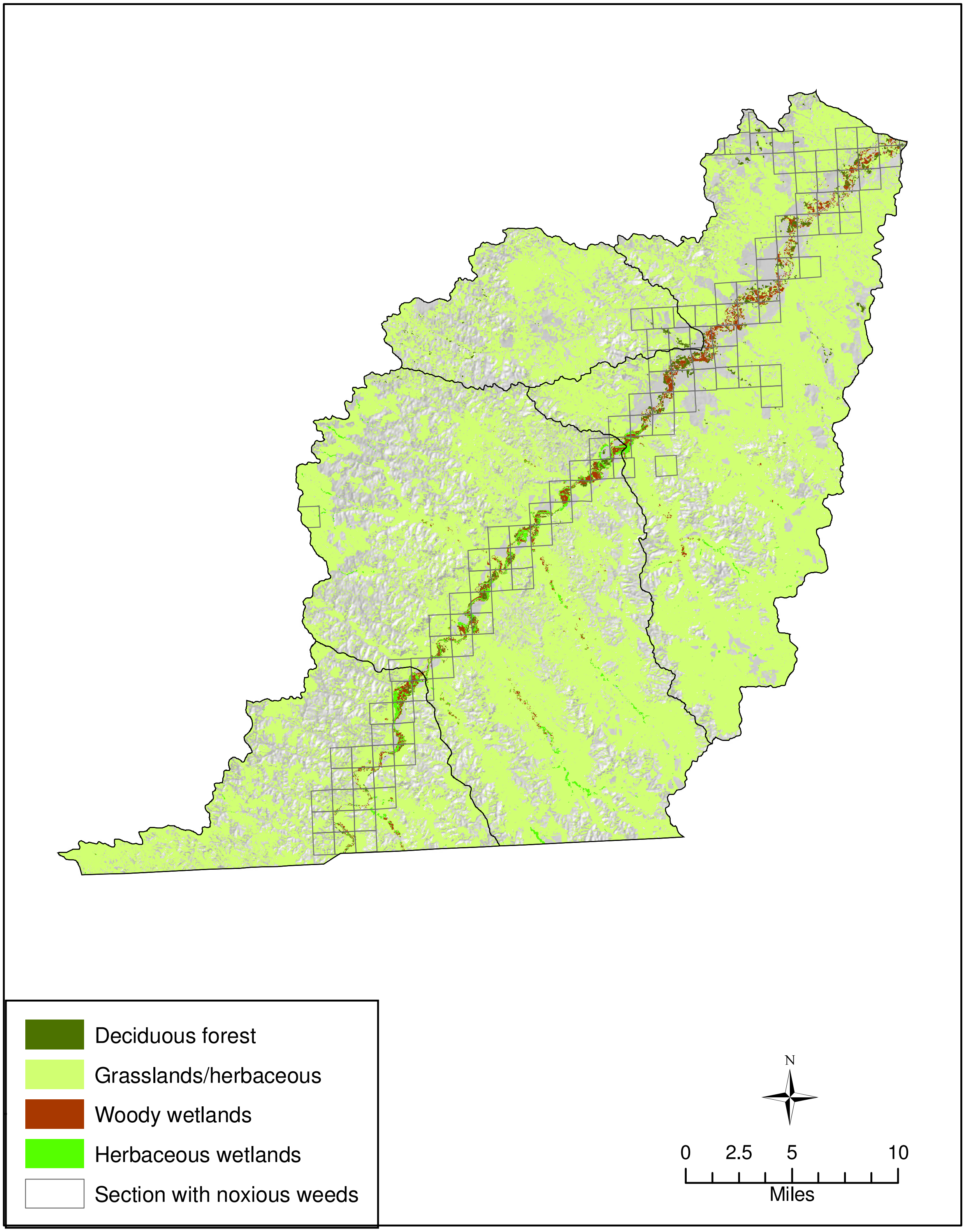


Figure 13. Public land survey sections with noxious weeds

extremely high. However, they are consistent across the three 5th code HUCs that include large portions of the Powder River corridor, suggesting that this is the area most susceptible to threats associated with various agricultural uses (i.e. grazing, weed invasion, and conversion).

Table 19. Composite Threat Index

	IRGT	INWT	IPAT	CTI
HUC 060	0.96	0.25	0.14	1.35
HUC 070	0.90	0.12	0.37	1.39
HUC 080	0.75	0.07	0.29	1.12
HUC 090	0.83	0.19	0.30	1.33

As noted above, we had no data allowing us to parse out the susceptibility of individual watersheds to impacts from coalbed methane extraction in the subbasin. However, we think it is reasonable to assume that given their proximity to Broadus, HUCs 080 and 090 would be particularly vulnerable to residential and commercial development pressures associated with CBM activity. All HUCs, but especially those with perennial streams and rivers, are vulnerable to the water quality issues associated with CBM, and HUC 060 and 070 are at risk from impacts originating in Wyoming as well as Montana. This risk will be discussed in greater detail in the section dealing with the fine-scale aquatic assessment work.

Interpreting the Broad-scale Assessment Composite Indices

Although it may be tempting to continue to reduce the composite assessment indices to a single number, we have chosen to keep them separate because we think that each represents a distinct and important piece of the watershed assessment. The Composite Natural Diversity Index provides a basis for assessing the raw material, i.e. the range of natural variability within the individual watersheds, which can be used as a surrogate for natural or background conditions. The Composite Watershed Condition Index provides an overview of the magnitude of change in natural conditions, allowing us to compare individual watersheds and tease out factors, like stream corridor land use patterns or road density, that exert measurable influence on overall condition. The Composite Threat Index is a measure of what can still be lost. This index should be interpreted on its own, or at most in relation to the Composite Watershed Condition Index. For example, HUC 070 ranks high on Composite Watershed Condition Index relative to the other watersheds, and also has a fairly high Composite Threat Index score. Examining the component parts of the CTI, one thing that emerges is the threat from agricultural conversion, which is higher in this HUC than elsewhere. One way to interpret this is as an early warning that this high-quality watershed has a significant amount of private land currently used for grazing and non-agricultural activities, and that it may be vulnerable to development pressures. However, only on-site investigation and discussion with private landowners can fully determine the extent of this vulnerability. Nonetheless, the composite indices provide a starting point for this and other inquiries.

Fine-scale Assessments

During the summer of 2005, MTNHP ecologists conducted rapid assessments of vegetation and detailed assessments of fish communities. The rapid assessments included descriptions of plant community composition and condition, and photos for each sites. Aquatic assessments include systematic surveys and sampling of macroinvertebrates and fish at six sites.

Vegetation Rapid Assessment and Photo Points

We completed 101 photo points throughout the subbasin (Appendix B) that were generally focused on riparian areas, which are the most ecologically important habitats in the subbasin. Photo point numbers that follow refer to the last four digits in the plot code. While each point has details specific to that area, some broader conclusions can be noted.

Overall, the ecological condition of the Middle Powder is relatively good compared to much of the region. Two species on the Montana noxious weed list, leafy spurge and saltcedar were noted during our surveys but they are not particularly widespread. The lack of water in many areas means that negative grazing impacts have largely been avoided. These ecologically intact grassland and sagebrush communities support diverse suites of native species, some of which have been identified as potentially declining or vulnerable either locally or regionally (Hiedel et al. 2002); the extensive nature of these habitats in the area adds additional ecological importance.

Other features of ecological significance in the county are the extensive sandy ecological sites, which appear as isolated but not uncommon areas of well-developed sandy habitat. These sites support many plant species of limited regional distribution or endemism that are Montana species of concern, and they also support distinctive plant communities (Hiedel et al. 2002).

The extensive riparian forests, primarily cottonwood, along the Middle Powder riparian corridor are also of considerable significance since few, if any other regional rivers have a similar length and breadth of this important habitat. Stands are often a few to several hundreds of yards wide and while there is agricultural development (primarily hayfields, 0040), other development is minimal outside of Broadus, allowing fairly continuous riparian forests through most of the watershed. Unfortunately, the trees are often decadent (0043) and new regeneration is almost totally absent, a typical condition in many Western riparian forests. Additionally, Russian olive (0032, 0033) and saltcedar are colonizing the riparian zone. These infestations could probably be controlled now with private landowner cooperation and adequate funding. If not controlled, these nonnatives will likely dominate in the future with potentially dire habitat consequences for some species (Kudray et al. 2004), especially if cottonwood establishment continues to be problematic. There is not sufficient research to determine exactly what species will be impacted from the replacement of cottonwood with Russian olive, but bat and bird species that rely on tree cavities for nesting will probably be detrimentally affected since cavities do not typically form in Russian olives (Kudray et al. 2004).

The shrub understory and herbaceous layers are also typical of most other riparian forests in Eastern Montana with considerably less diversity than presettlement conditions. Shrub presence and cover is low and the nonnative smooth brome dominates the herbaceous layer.

The condition of riparian forests and shrubland habitats varied considerably among the subwatersheds. In the following paragraphs, we summarize our observations. Rather than organize these observations by 5th code HUC, we describe the east side of the Middle Powder first, beginning in the south and moving north, then describe the subwatersheds on the west side of the river, again beginning in the south and moving north. Although there are considerable similarities in condition within 5th code HUCs, similarities in composition tend to sort out on east-west and north-south axes and along elevational gradients, with communities on the eastern side of the river often more similar to each other than to communities on the western side. However, we have included 5th code HUC numbers for reference.

Some smaller tributaries, like Dry Creek (HUC 060), had little woody riparian vegetation with the exception of some scattered cottonwood, ponderosa pine and Rocky Mountain juniper with snowberry and rose (*Rosa* spp.) shrubs mostly on steep north facing slopes (0004, 0008, 0011). These conifers are fairly common in the riparian zones of small, often incised tributaries while cottonwoods mixed with green ash (*Fraxinus pennsylvanica*) and box elder (*Acer negundo*) occur in the riparian zones of larger tributaries. Large diameter woody debris was often all that remains as evidence of original cottonwood tree cover (0001).

The Bay Horse Creek subwatershed (HUC 070) has low hills and a broad valley with common but decadent cottonwoods (0017, 0018). Wetlands are rare throughout the Middle Powder River subbasin and most have been either altered to enhance use as a stock pond or are wetlands created for stock watering through dam building. Photo point 0018 is an example of a good condition floodplain wetland within this subwatershed. Agriculture (hay fields, pastureland) is common further up this drainage

(0019, 0020), but riparian forests are intermixed (0020).

The lower Buttermilk Creek drainage (HUC 070) also has common decadent cottonwoods with little if any secondary shrub development (0021). The floodplain is often fairly wide, up to 10 meters, and is generally in good condition with little trampling of banks, although the riparian vegetation usually lacks a woody component other than sagebrush and a few scattered trees (0022, 0023). The uplands are mostly grasslands of moderate or better condition although cheatgrass and Japanese brome are quite common (0025). Sandstone outcrops are common with a strong influence on the vegetation immediately down slope. Needle and thread often dominates on these toeslopes where soils have more sand than lower, flatter lands where blue grama, Western wheatgrass, and the annual bromes dominate. Some of these stands receive additional moisture from steep slopes above and look quite productive (0024).

The Butte Creek valley (HUC 090) has woody riparian habitats in relatively good condition, especially in the upper valley where there are numerous woody draws with a mix of shrubs and trees (0026, 0027, 0028, 0030). The pasture and hay fields here are dissected by tributaries, and some have a fairly diverse mix of shrubs (0030). As elsewhere throughout the Middle Powder River subbasin, the higher hills have a mix of ponderosa pine and Rocky Mountain juniper that is generally in good conditions with few invasive species and limited grazing impacts. This valley has considerable amounts of sandy soils with dominance by needle and thread. Little bluestem is also noticeable as patches on steep grassland slopes (0029); threadleaf sedge increases on steeper eroding slopes. Crested wheat becomes more abundant further up the valley.

Hay fields and crested wheat are common throughout much of the Baking Powder Creek valley (HUC 090), which is relatively broad and flat compared to some sub-watersheds within our study area. Woody riparian areas are not common until further up the valley. Here, riparian zones are in good condition structurally, with fairly dense tree cover and a variety of shrubs and small trees in the understory (0035, 0036, 0037).

The First Creek subwatershed (HUC 090) has only a few scattered cottonwoods downstream towards the Middle Powder River where the floodplain is in a low broad terrace bracketed by steep gully sides (0038). However, cottonwood riparian forests extend upstream of the road for a considerable distance (0039). Second Creek (HUC 090) has limited woody vegetation (0041). Most of the trees along the Third Creek (HUC 090) riparian zone have already died (0044).

The Coyote Creek subwatershed (HUC 090) north of Broadus has some of the heaviest sagebrush cover in our study area (0047). Low rolling hills with sage and mostly needle and thread grasslands transition fairly abruptly to the watershed divide of steep eroded hills with common tree patches (0047). The riparian zone lower in the subwatershed is deeply incised, with scattered cottonwoods that rapidly disappear further up the creek (0046).

The southwestern part of the subbasin has rugged topography and is more heavily forested. Rough Creek (HUC 060) is the subwatershed furthest south on the west side of the river that we assessed. There was no obvious water development so little adverse effects associated with grazing were noticed. Wyoming big sagebrush is mixed with a variety of grass species; favorable aspects and landforms are forested with ponderosa pine and Rocky Mountain juniper (0097, 0098, 0099). Sandstone outcrops are common (0101). Much of the next watershed to the south, Bradshaw Creek, burned a few years ago (0100).

The vegetation of Graham Creek (HUC 060) is in good condition and varies with the topography; the common steep areas have little vegetation at all, while elsewhere bluebunch wheatgrass and sage shrublands intermix with sparse to relatively dense ponderosa pine and Rocky Mountain juniper forests and woodlands (0048). The upper valley is somewhat less rugged with a similar mix of sagebrush, grasslands, and wooded areas (0049). Some forests have been thinned. Other photo points west of the Middle Powder River (0050, 0051, 0052, 0053, 0054, 0055, 0056) show similar and typical landscape patterns in this area of rugged topography: incised drainages, common steep barren slopes, conifers mixed with some hardwood trees or shrubs in the narrow floodplains, and a matrix of sagebrush, conifer woodlands, and grasslands.

The river valley starts to broaden near the Spring Creek (HUC 070) area (0057) but steep barren hills (0058, 0059) and deeply incised gullies (0060) are still common, although there is not as much tree cover.

The Bloom Creek valley is generally in good condition with common woody riparian vegetation that occasionally has good woody species diversity and a variety of shrub/tree layers (0064). In the lower valley cottonwoods are relatively common but widely scattered with a mix of other woody species (0061, 0062, 0065). Further up the valley, green ash becomes more abundant in the riparian zones while ponderosa pine and Rocky Mountain juniper are relatively dense along the slopes. Silver sage (*Artemisia cana*) is abundant throughout the sub-watershed (0063).

The small watersheds north of Bloom Creek on the west side of the Middle Powder River have limited access so they were not assessed, but the views from the road indicated a landscape with steep, often relatively barren hills with few trees and valleys with abundant sage and often crested wheat (0066, 0067, 0068, 0069). A few decadent cottonwoods were the most woody vegetation any of these small riparian areas had other than a stock pond in Fire Gulch that was ringed with trees.

The Dry Creek (HUC 090) on this side of the river had little woody riparian vegetation other than silver sage and a few conifers (0070, 0071, 0072). Nonnative plants like leafy spurge and crested wheat are well established here. Otherwise, the vegetation in this subwatershed looks similar to those described in the preceding paragraph.

Flood Creek (HUC 090) has a substantial reservoir that is well used by cattle (0073), as are the surrounding uplands. Silver and Wyoming big sage are common here. Other landforms and vegetation (0074) are similar to adjacent sub-watersheds with the exception of Cedar Creek (HUC 090), which has considerably more tree cover (0075).

Rock Springs Creek (HUC 080) is a large tributary with a broad valley and extensive woody riparian vegetation (0077). The lower valley has active agricultural activities, primarily hay fields. Where public land access was available upstream the channel was deeply incised and likely no longer reaches the historic floodplain (0078, 0079). Leafy spurge is abundant, and Japanese brome is also common with other upland vegetation reflecting high utilization by cattle. Woody riparian vegetation is common but not abundant in the upper valley (0081). Vegetation on the steep eroded slopes at the edge of the valley (0080) is similar to the rest of the Middle Powder River watershed with a black greasewood / bluebunch wheatgrass vegetation community, although Wyoming big sagebrush is often the dominant, with black greasewood and fourwing saltbush (*Atriplex canescens*) the other common shrubs. Smaller tributaries at the head of the valley have conifers in favorable moisture locations (0082).

A drainage north of Rock Springs Creek is relatively unique in our watershed study area with a diverse mix of woody vegetation in a flat bottom canyon (0083, 0084). Much of this upper end of the subbasin south of Broadus is a relatively broad valley with increased agricultural activity and crested wheat grasslands (0085, 0087, 0088). Steep hillsides with scattered patches of trees and sparsely vegetated slopes border the valleys. Woody riparian vegetation is relatively sparse (0089) or patchy (0086, 0096). An unnamed tributary about 4 miles south of Broadus on the west side of the river may be typical of the conditions in this area. The stream channel is somewhat incised (0090, 0091) with only scattered woody riparian vegetation. There are a variety of grass species mixed with common Wyoming big sagebrush; conifers are scattered (0092). The topography becomes more rugged near the head of the valley with larger and denser forested cover

(0093). There is a relatively large reservoir in this valley (0094).

Fish and Macroinvertebrate Assessments

The Powder River is one of the last undammed, large prairie river systems in the United States, with sweeping meanders across the valley bottom, side channels, oxbows, shifting islands and functional connectedness to the floodplain. The aquatic ecosystem in the larger basin supports many elements of community function and biological diversity associated with its physical setting, including 25 native fish species (19 in Montana) and numerous Species of Concern invertebrates. With its specialized aquatic life, the Powder River represents the sole remnant of a once widespread Great Plains riverine community of fish and invertebrates (Hubert 1993), one of the most understudied and endangered aquatic systems in North America (Dodds et al 2004). Furthermore, the Powder River provides substantial habitat for the declining sturgeon chub (*Macrhybopsis gelida*), a Montana Species of Concern that has been extirpated from much of its historic range (Werdon 1994). In Wyoming, the Powder River was identified by Patton et al. (1998) as supporting an abundance of species adapted to turbid rivers that have been greatly reduced or eliminated from other drainages: the flathead chub (*Platygobio gracilis*), plains minnow (*Hybognathus placitus*), western silvery minnow (*Hybognathus argyritis*), river carpsucker (*Carpoides carpio*), and the channel catfish (*Ictalurus punctatus*). Stagliano (2005) identified the Powder River as the reference standard in the Large Prairie River classification; no other large prairie system in Montana contains the quality and biological integrity of its communities and habitats. The Powder River has been identified as the primary spawning area for the lower Yellowstone River population of sauger (*Stizostedian vitreum*, a Montana Species of Concern), as well as other species that migrate from the Yellowstone River to these tributaries to spawn (Rehwinkel 1978, Backes 1994, Riggs and Gardner 2000). These include the blue sucker (*Cycleptus elongatus*), shovelnose sturgeon (*Scaphirhynchus platorhynchus*), burbot (*Lota lota*), and channel catfish.

The invertebrate communities in the Powder River are also significant. Rehwinkel (1978) concluded that the Powder River supported the most unique community of benthic invertebrates in Montana. More recent investigations (2000-2002) by Dan Gustafson (personal comm. 2006) and sampling in this study indicate that some of these specialized mayflies (Ephemeroptera) are in decline. Six of these globally rare to uncommon mayfly species (*Analetris eximia, Anepeorus rusticus, Raptoheptagenia cruentata, Ametropus neavei, Homoeoneuria alleni, Lachlania saskatchewanensis*) are included on the 2006 Montana Species of Concern list (Montana Natural Heritage Program 2006). These species were probably once quite common in prairie rivers in the northern Great Plains, but have been eliminated throughout most of their historic range, at least partly due to impoundments and other anthropogenic river alterations.

The Powder River Basin in Wyoming and Montana is currently undergoing one of the world's largest coalbed methane developments with about 12,000 wells in place in 2003, 14,200 in 2005, and up to 70,000 projected over the next 20 to 30 years (Davis and Bramblett 2006). Coal bed methane mining has the potential to severely disrupt the ecosystem and harm its biota, both in the riparian zone and within the stream itself. The interconnectedness of rivers with their watershed renders any lotic ecosystem vulnerable to threats from human activities anywhere in the landscape (Allan et al. 1997). Numerous aquatic and fisheries professionals have commented on the potential consequences of CBM mining within the watershed in an EIS report to the BLM (USDI 2003).

Sites chosen for this study

Working with BLM biologist Joe Platz, we chose sites along the Middle Powder River on BLM-managed land that would complement USGS monitoring sites (see Figure 6 and Table 20). Five

Table 20. Powder River aquatic sampling sites

Site Number	Description	Latitude	Longitude	Elevation (ft)	Date sampled
Powder River 1	Powder River at Wyoming border	45.01504	-105.906	3415	7/11/2005
Powder River 2	Powder River @ Dry Creek	45.03771	-105.881	3391	7/11/2005
Powder River 3	Powder River at Jenkins Creek	45.10619	-105.838	3314	7/11/2005
Powder River 6	Powder River at Buttermilk Creek	45.22560	-105.691	3185	7/12/2005
Powder River 5t1	Powder River upstream Rough Creek	45.34667	-105.533	3105	6/3/2005
Powder River 5t2	Powder River upstream Rough Creek	45.34667	-105.533	3105	7/12/2005
Bloom Creek	Downstream Hailstone Spring	45.23333	-105.899	3757	5/20/2005

Powder River reaches were established with GPS points, flagging and site photos at the 0, 300 and 450 meter points. Numerous tributary sites on BLM lands were visited (~19 stream miles) in the watershed for possible lotic sampling, but were consistently dry. These included Bitter Creek, Buttermilk Creek, Jenkins Creek, Rough Creek (north and south), Buffalo Creek, Dry Creek and Maverick Prong of Bloom Creek.

Sampling approach

Aquatic communities (fish and macroinvertebrates) and riparian areas were inventoried and assessed using a combination of protocols developed by Montana Fish, Wildlife and Parks and BLM / EPA. Reach lengths were set as a standard 300 meters, but to encompass an additional set of riffle macrohabitats for the macroinvertebrate targeted-riffle sampling, protocols were extended to 450 meters.

Habitat and Water Quality Collection and Analysis

For each sampled reach, we completed a visual rapid habitat assessment (Barbour et al. 1999) based on 10 habitat variables (instream fish cover, epifaunal substrate, pool substrate characterization, pool variability, channel alteration, sediment deposition, channel sinuosity, channel flow status, bank condition, bank vegetative protection, riparian vegetated zone width). The habitat quality scoring is based on a maximum score of 200. At each reach, we also measured channel wetted width (in meters), and recorded channel depths (in centimeters) at ¼, ½ and ¾ wetted width at each of the three flagged transects. Substrate was evaluated based on Wolman size-classes (Wolman 1954) in percent per size class at 10 additional transects spaced 30 meters apart perpendicular to the stream channel. Prior to biological sampling, we measured specific conductivity, pH, water temperature and dissolved oxygen concentration with a Yellow Springs Instruments, Inc. Model 85 water quality meter calibrated to the higher conductivity level.

Fish Collection and Analysis

Fish surveys used a modification of the 300 meter seining protocols developed by Bramblett (2005) for Montana Fish, Wildlife and Parks. This protocol calls for block nets at the upstream and downstream ends of the reach, but the width of the Powder River precluded the use of these. Instead, shallow riffle areas were used as barriers and were probably sufficient to prevent fish from escaping while the run and pool areas were being seined (Figure 14). Shallow riffle areas with rock obstructions were "kick-seined" (Figure 15). We used 30 foot ¼ inch mesh seines to cover most areas across the channel and in all macrohabitats within the reach. Fish were transferred to holding

Figure 14. Seining near Wyoming border

Figure 15. Kick-seining a riffle

buckets, identified to species, counted, examined for external anomalies (e.g. deformities, eroded fins, lesions, and tumors), and then released. Young-of-the-year fish less than 20 millimeters in length were noted on the field sheet (but not included in the totals) and released. Voucher specimens were only taken in the case of uncertain field identifications of the silvery minnows (*Hybognathus* spp.) which were preserved in 10% buffered formalin and identified in the lab. Vouchers will be submitted to the Montana State University fish collection.

Analysis of the sampled fish communities used Integrated Biotic Indices (IBI) (Bramblett et. al 2005) and derived Observed/Expected (O/E) Fish Models (Stagliano 2005) to detect impairment in the biological integrity of the sites. The IBI calculates a series of metrics evaluating different attributes of the community (Table 21). Because fish taxa richness is expected to be directly proportional to watershed size, we used an average catchment area for this reach (20,962 km^2) based on data from the Moorhead gauging station. The metrics yield an overall score between 0 and 100. Bramblett et al. (2005) did not propose threshold criteria for good, fair, and poor biological integrity

Table 21. Fish metrics and classification of fishes captured on the Powder River (2005).

Species	Scientific Name	Trophic*	Feeding Habitat†	Litho-obligate Reproductive Guild‡	Tol**	Origin ††
Hiodontidae						
Goldeye	*Hiodon alosoides*	IN	WC	LO	INT	N
Catostomidae						
River carpsucker	*Carpiodes carpio*	OM	BE	LO	MOD	N
Shorthead Redhorse	*Moxostoma macroledidotum*	IN	BE	LO	MOD	N
Cyprinidae						
Common carp	*Cyprinus carpio*	OM	BE		TOL	I
Flathead Chub	*Platygobio gracilis*	IN	GE		MOD	N
Longnose dace	*Rhinichthys cataractae*	IN	BE	LO	INT	N
Plains minnow	*Hybognathus placitus*	HB	BE		MOD	N
Western silvery minnow	*Hybognathus argyritis*	HB	BE		MOD	N
Sand shiner	*Notropis stramineus*	OM	GE	LO	MOD	N
Sturgeon Chub	*Macrhybopsis gelida*	IN	BE	LO	INT	N
Cyprinidontidae						
Plains Killifish	*Fundulus kansae*	OM	GE		TOL	I
Ictaluridae						
Channel catfish	*Ictalurus punctatus*	IC	BE	TR§	MOD	N
Stonecat	*Noturus flavus*	IC	BE	LO	INT	N

*HB = herbivore (> 90% plants or detritus); IC = invertivore/carnivore (>25% both invertebrates and vertebrates); IN = invertivore; OM = omnivore(25-90% plants or detritus)
† BE = benthic; GE = generalist; WC = water column: Brown (1971); Scott and Crossman (1973); Becker (1983)
‡ LO=Litho-obligate Reproductive Guild; Scott and Crossman (1973); Pflieger (1997); Barbour et al. (1999)
§ Tolerant reproductive strategists are not litho-obligates, use parental care at spawning site: Scott and Crossman (1973); Pflieger (1997)
** INT = intolerant; MOD = moderately tolerant: TOL = tolerant; Barbour et al. (1999);
†† N = native; I – introduced; Brown (1971); Holton and Johnson (2003)

for these scores. Therefore, we used 75 to 100 as an indicator of good to excellent biological integrity, 25 to 74 as an indicator of fair biological integrity, and <25 as an indicator of poor biological integrity.

The O/E (observed taxa of an evaluated site/ expected taxa for a reference site) model is a direct measure of the biological community. It compares the taxa that are expected at a site (carp and introduced fish are never "expected" and given zeros) with the actual taxa that were found when the site was sampled. Expected fish communities are derived by identifying the frequency of occurrence that a species has at a site classified in a reference condition and summing the frequencies across all fish species of the community (see Appendix C).   In some cases it is more ecologically meaningful than the IBI, but not always.

Macroinvertebrate Collection and Analysis
Paired macroinvertebrate samples taken at each site allowed a comparison of two differing sampling protocols, the EMAP Targeted Riffle (8 composited Surbers) and the EMAP_Reach-Wide Multi-habitat (Lazorchak 1998), Samples were taken in July 2005 and processed (sorting, identification, and data analysis) by David Stagliano at the Montana Natural Heritage Program Helena lab. Macroinvertebrates were identified to the taxonomic level specified by the Montana Department of Environmental Quality (DEQ) and biological metrics were calculated from the data. Montana Department of Environmental Quality's newest multimetric macroinvertebrate (MMI) protocols (Jessup et al. 2005, DEQ 2006) were used to analyze the macroinvertebrate samples. Metric results were then scored using the Montana DEQ bioassessment criteria with each sample categorized as non-impaired or impaired according to threshold values. Relativized abundance data was used in a cluster analysis with PC-ORD software.

The macroinvertebrate MMI score is based upon a series of metrics that measure attributes of benthic macroinvertebrate communities that reflect condition changes to a stream system (from pollution or pollutants). The individual invertebrate metrics include:

- **EPT Taxa Richness** (Score = EPT richness/14*100): Ephemeroptera, Plecoptera and Trichoptera taxa;
- **Percent Tanypodinae** (Score = PercentTanypodinae/10 *100): Tanypodinae is a subfamily within the family Chironomidae;
- **Percent Orthocladiinae of Chironomidae** (Score = (100-percent Orthocladiinae of Chironomidae/ 100)*100);
- **Predator Taxa Richness** (Score = number of predator taxa/9*100);
- **Percent Collectors and** Filterers (Score = (100 – percent collectors and filterers/65)*100). This metric measures the relative abundance of collector and filterer taxa in the sample.

The MMI score represents the condition of the macroinvertebrate community at the time the sample was collected. If the index score is below the impairment threshold, the individual metrics can be used to provide insight as to why the communities are different from the reference condition (Barbour et. al 1999, Jessup et. al. 2005). The results are averaged to obtain the final index score. The impairment threshold set by Montana DEQ is 37 for the eastern plains stream index (Table 22).

Table 22. Impairment determinations from the MMI and O/E (RIVPACS) (taken from Jessup et al. 2005 and Feldman 2006)

Ecoregion	RIVPACS	MMI	Impairment Determination
Mountain	≥ 0.8 or ≤ 1.2	≥ 63	Not impaired
	< 0.8 or > 1.2	< 63	Impaired
Low Valley	≥ 0.8 or ≤ 1.2	≥ 48	Not impaired
	< 0.8 or > 1.2	< 48	Impaired
Eastern Plains	≥ 0.8 or ≤ 1.2	≥ 37	Not impaired
	< 0.8 or > 1.2	< 37	Impaired

Habitat and Water Quality Results and Discussion

Powder River Sites 1 and 5 scored highest in habitat quality on both the BLM and EPA rapid bioassessment protocols, with 70% and 85% of the best possible score, respectively (Table 23). Site 5 also had the highest number of recorded channel depths greater than 50 centimeters, indicating ample deep holding areas for fish. Powder River Site 3 scored lowest in both habitat assessment scores despite having the second highest number of channel depths greater than 50 centimeters. Many of these deep areas had too much unsuitable, unconsolidated substrate (silt, fine sand) to be considered optimum fish habitat. Diurnal progression of temperature increases and dissolved oxygen (DO) decreases can be seen with sites 1, 2 and 3. Site 1 was sampled in the morning; by the time Site 3 was sampled in the late afternoon, water temperatures increased more than 8 ° C and DO decreased by more than 1mg/L. With dissolved oxygen levels already fairly low, it is possible that a 1 mg/L decrease through the day may affect fish presence at a given site.

Fish Community Results and Analysis

Thirteen species of fish (11 natives) were identified from 1299 individuals collected from the 6 samples at the 5 Powder River sites (Table 24). No fish were observed or collected at the Bloom Creek upstream site. There was an average of 7 native fish species per site, representing 2 species group assemblages, the Medium Warmwater River and the Core Prairie Stream Assemblage (Stagliano 2005, Appendix E). Sites 1 and 5 had the highest average species richness with 8 each, and no non-native species were sampled. Site 5 was also the only site where we collected the sturgeon chub, a Montana Species of Concern, during both the June and July sampling periods.

There was a temporal shift in fish communities from June to July at site 5, with substantial decreases of longnose dace, flathead chubs and channel catfish and an increase in sand shiners, goldeyes and river carpsuckers (Table 25). This widely fluctuating community structure (with only 51% similarity between dates) is typical of rivers where there are variable flow conditions and migratory spawning fish species.

The longnose dace, flathead chubs, sand shiners and channel catfish all showed signs of spawning (e.g. male spawning colors, pregnant females) during the June sampling date, but not in July. Since this site (Site 5) had extensive gravel runs, it was likely being used by most litho-obligate reproductive species in the vicinity. By July, sand shiners had become the dominant minnow species. The dominant species by percentage across all

Table 23. Habitat quality scores, and physical and water quality parameters of Middle Powder sites

Site No.	BLM Site Score	EPA RBP Score	Avg wetted width (m)	Avg channel depth (cm)	# CD[1] >50cm	H_2O Temp (°C)	ph	Cond*	DO^
Powder River 1	17	170	42.4	38.2	8.0	19.8	8.5	1120	4.4
Powder River 2	15	164	38.5	38.5	7.0	24.5	8.5	1140	3.7
Powder River 3	14	139	44.0	43.5	15.0	27.9	8.6	1130	3.3
Powder River 6	14	146	45.0	30.8	7.0	21.9	8.4	1222	4.8
Powder River 5t1	16	172	41.0	na	na	15.3	8.2	1180	8.0
Powder River 5t2	16	172	37.0	39.5	16.0	27.7	8.4	1350	4.7
Bloom Creek	12	137	1.9	10.5	0.0	16.5	8.1	680	4.0

CD[1] -channel depths reflecting deep run or pool areas
*Conductivity—microsiemens/cm
^Dissolved Oxygen—mg/l
na-data not taken on this date

Table 24. Fish collected from the mainstem Powder River, IBI and O/E index scores

Powder River	Site 1	Site 2	Site 3	Site 6	Site 5t1	Site 5t2
River Mile	219	215.4	206.6	186.9	166.2	166.2
Collection date:	7/11/2005	7/11/2005	7/11/2005	7/12/2005	6/3/2005	7/12/2005
Channel Catfish	3	4	1	0	11	2
Common Carp	0	2	0	0	0	0
Flathead Chub	96	47	30	26	116	46
Goldeye	3	0	2	0	0	3
Longnose Dace	3	2	3	0	62	1
Plains Minnow	12	0	3	1	5	1
Plains Killifish	0	0	0	2	0	0
River Carpsucker	1	0	0	1	0	3
Sand Shiner	305	97	19	47	97	224
Shorthead Redhorse	1	0	0	0	0	0
Stonecat	0	2	0	0	0	0
Sturgeon Chub*	0	0	0	0	2	1
Western Silvery Minnow	0	2	2	1	6	1
Total # species	**8**	**7**	**7**	**6**	**7**	**9**
Native Species	**8**	**6**	**7**	**5**	**7**	**9**
Total Individuals	**424**	**156**	**60**	**78**	**299**	**282**
IBI	**64**	**56**	**57**	**52**	**61**	**67**
O/E converted to %	**101**	**76**	**89**	**63**	**89**	**114**

Table 25. Temporal shift in fish communities, Site 5

Powder River (Site 5)	6/3/2005	7/11/2005
Channel Catfish	11	1
Goldeye	0	3
Longnose Dace	62	1
Flathead Chub	116	46
Sturgeon Chub	2	1
Sand Shiner	97	224
River Carpsucker	0	3
Plains Minnow	5	1
Western Silvery Minnow	6	1
% Community Similarity		**50.6**
Taxa Similarity		**77.8**

sites were the sand shiner (61%), flathead chub (28%), and longnose dace (5%), followed by the channel catfish (2%), plains minnow (2%), goldeneye (1%), and western silvery minnow (1%).

IBI vs. O/E

Even when Powder River sites had their full fish community present (Site 5), they still ranked low (fair) in biointegrity using the IBI (Figure 16). Part of this may be because sites with the lowest scores were those with adjustments for catchment area, which effectively reduced the significance of the number of native species and number of native families. The Powder River is a diverse system, and assuming a linear correlation between fish species and watershed area, as the IBI does, may not be valid with a watershed of this size. The largest catchment area in the sites used by Bramblett et al. (2005) to develop the fish IBI was less than 14,000 km^2 while catchment areas for our

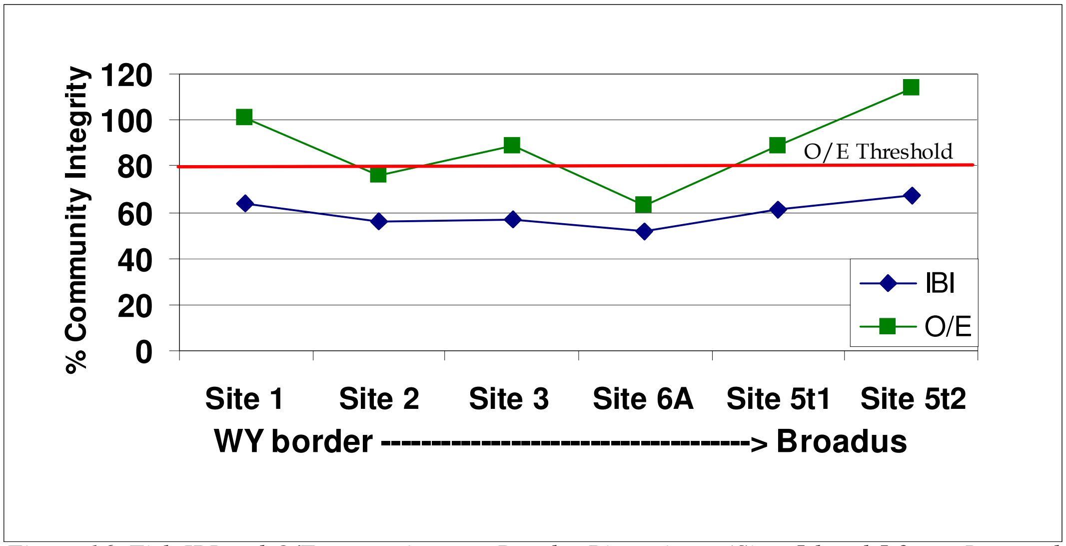


Figure 16. Fish IBI and O/E comparisons at Powder River sites. (Sites 5tl and 5t2 are June and July samples at Site 5, respectively).

sites on the Powder River ranged from ~20,000 km^2 to well over 23,000 km^2.

Because this IBI assesses biotic integrity relative only to current conditions, we cannot compare present conditions to presettlement environments. However, by using the expected fish community from a reference large prairie river, we can derive a list of the fish species under the best possible conditions given minimal anthropogenic stressors. The best expected overall fish community in the upper reaches consisted of an average of 7.5 native species.

For the Middle Powder River assessment of fish communities, the Fish IBI (Bramblett 2005) was inadequate to determine fish community integrity, although it did correlate strongly with the habitat quality index ($r = 0.74$, $p < 0.05$). IBI values continually ranked the sites as having fair biological integrity. On two sites with long stretches of monotonous sandy-glide habitat, we failed to capture 100 fish individuals, which may have affected the fish community metrics.

Historical Perspectives on Powder River Fish Communities

We compiled historical and riverwide data in an effort to determine what a native Montana Powder River fish community might look like. These data were from the Montana Fish Wildlife and Parks MFISH database of fish collections reported in the Powder River over the past 30 years, including the MTNHP and USGS collections in 2005 from sites in the Middle Powder sub-watershed from the WY border to Broadus. We also used a report from Confluence Consulting (Endicott 2004) for Wyoming, because it gave us additional main-stem sites to review.

Sampling during 1975 found 19 species of fish (17 natives) in the Montana section of the Powder River, while a cumulative look at samples since then show 18 fish species (15 native) (Table 26). Lake chubs (*Couesius plumbeus*) reported by Bruce Rehwinkel from 4 of 7 sites in 1975 and 1976 seem to have disappeared from the entire Powder River System, as have the brassy minnow and the green sunfish, both represented by one individual at the Locate, MT site in 1975. The creek chub was reported once (2 individuals) in 1975, and has not been reported in Montana's Powder River since, but Confluence Consulting (2004) reported one creek chub collected approximately 15 miles from Montana at river mile 235 (However, given the ecological requirements of creek chubs, brassy minnows and green sunfish, they were presumably "wash-ins" from Mizpah Creek which joins the Powder River approximately 3 miles upstream of this sampling site).

Table 26. Cumulative species list and site occurrences. Asterisk (*) indicates fish species that have not been collected since the 1970's collections

	1975 (n=7)	2005 (n=28)
Brassy Minnow*	14.3	0
Burbot	28.6	12
Channel Catfish	100	96
Common Carp	28.6	24
Creek Chub*	14.3	0
Flathead Chub	100	96
Goldeye	57.1	64
Green Sunfish*	28.6	0
Lake Chub*	57.1	0
Longnose Dace	71.4	48
Longnose Sucker	0	8
Plains Minnow	42.9	44
Plains Killifish	0	8
River Carpsucker	57.1	56
Sand Shiner	14.3	40
Sauger	28.6	40
Shorthead Redhorse	28.6	48
Shovelnose Sturgeon	14	24
Stonecat	14.3	12
Sturgeon Chub	100	48
Walleye	0	20
Western Silvery Minnov	71.4	60
Total Species	**19**	**18**
Total Native Species	**17**	**15**

An examination of one of the shared collection sites at river mile 219 shows that the Percent Community Similarity is very low at 24%, and more surprisingly, the taxa similarity is only 58% (Table 27). Five of the 12 species were not shared between the samples, and 2 common taxa collected in 1975, lake and sturgeon chubs, were absent from the 2005 samples. In fact, sturgeon chubs have not been collected within 30 miles of this site in the past five years. There has also been a shift from a flathead chub-dominated community to a sand shiners-dominated community. This pattern may have to be further investigated to determine whether sand shiners are more tolerant and if their increasing numbers represents declining water quality.

Table 27. Powder River fish samples at the Wyoming border taken 30 years apart

Taxa	**15-Oct-75**	**11-Jul-05**
Channel Catfish	1	3
Common Carp	4	0
Goldeye	10	3
Longnose Dace	3	3
Flathead Chub	965	96
Lake Chub*	33	0
Sturgeon Chub*	25	0
Sand Shiner	5	305
River Carpsucker	3	1
Shorthead Redhorse	7	1
Sauger*	1	0
Plains Minnow	0	12
O/E	**1.27**	**1.13**
Percent Community Similarity		**24.60%**
Taxa Similarity		**58.30%**

Sturgeon chubs, a Montana Species of Concern and a former Endangered Species Act candidate, occurred in all of Bruce Rehwinkel's samples in 1975 and 1976 and were 5% of the species community. In the past 5 years the sturgeon chub has been collected at less than 50% of the Powder River sites sampled and is usually represented by only 1 or 2 individuals per sample (<1% of the community). The rarity of sturgeon chubs is alarming for a river that presumably provides the most substantial habitat for this declining species (Patton et al. 1998). The U.S. Fish and Wildlife Service's recent status report states sturgeon chub may be in danger of extinction in pertinent Montana waters except in the Powder River (Werdon 1993). By contrast, walleye were not found in the earlier samples, but today occur in about 20% of sites sampled. Plains killifish (*Fundulus zebrinus*), an introduced fish, has also appeared in the Powder River samples more recently. Generally, they are only represented by one or two individuals in each sample, but any noticeable increases in the numbers of this species could be indicative of decreasing water quality. The plains killifish is tolerant of high salinities and alkalinities and is able to withstand extremes in these water chemical parameters long after other fish are gone (Baxter and Stone 1995). Sand shiners are also collected more frequently now (40% vs. 14% of sites) and comprise a much higher percentage of the fish community that they did in the 1970s.

Macroinvertebrate Community Analysis

Macroinvertebrate taxa lists and abundances for each sample can be found in Appendix D. Overall, 59 taxa were reported, with indicator species from 3 distinct species assemblages (Appendix F). Average taxa richness per site was 23.4 taxa. The Species of Concern mayfly, *Raptoheptagenia cruentata* (G4, S2), was found at all sampled sites, and most abundant in the targeted-riffle samples. The other rare mayflies, *Anepeorus rusticus* (G1, S1) and *Homoeoneuria alleni* (G4, S2), were only found at the Dry Creek site 2 in the reach-wide sample, represented by 2 individuals each. There was no significant difference in the number of taxa sampled in the targeted riffle (TR) vs. reach-wide (RW) EMAP samples (F test, p=0.68). The number of individuals obtained in a sample was significantly higher in the TR vs. RW EMAP samples (F test, p<0.0001). Two TR samples had to be sub-sampled to reduce the number of organisms to obtain the targeted 500 count. Targeted-riffle samples across all sites were more similar to each other than they were to the same site reach-wide EMAP samples (Figure 17). In fact, samples using the reach-wide protocols produced 2 distinct community clusters (Figure 17, species groups 2 and 4), representing the different macrohabitats being sampled. Because of this, we suggest that targeted-riffle sampling be used in future surveys.

Despite clear separation of the 2 EMAP methods in a cluster analysis, the Montana multi-metric scores (MMI) did not significantly vary and the sites were all classified in the non-impaired category (Table 28). However, there is a 20 point scoring spread from the lowest to highest MMI scores (45.5 at Site 2 RW to 65.4 at Site 5 RW). Site 5 (RW and TR) and site 3 targeted-riffle scores indicate sites with the highest macroinvertebrate community integrity. However, the metrics chosen for this eastern plains MMI do not seem to represent the unique invertebrate community of the Powder River very well. Two of the metrics, % Tanypodinae and % Orthocladiinae of Chironomidae, have no scores in 8 of the 10 samples evaluated, since no individuals of these taxa were collected (Appendix E). We recommend an evaluation of other metrics for the Powder River to obtain more robust community measures, or to further develop an invertebrate O/E, as we did with the fish communities in the Powder Watershed.

When we compared the results of macroinvertebrate sampling to the results of fish sampling, we found that EMAP Targeted Riffle samples correlated with the fish O/E scores more closely than the reach-wide samples (TR x O/E, r=0.87 p<0.01 vs. RW x O/E, r=0.41 p>0.05)

Figure 17. Cluster analysis of relativized macroinvertebrate abundance analysis data taken with the two EMAP protocols

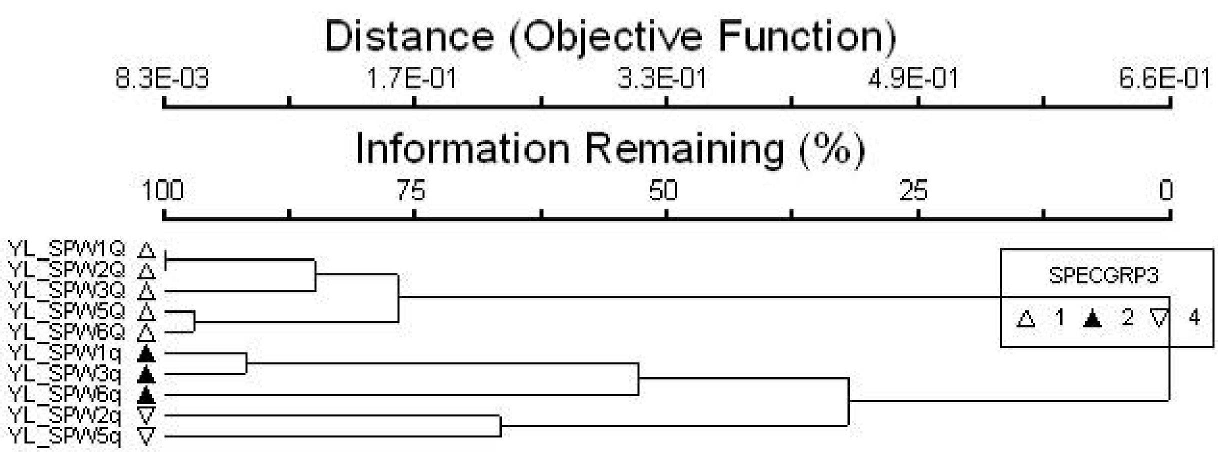


Table 28. Overall macroinvertebrate results for each stream site

Site	site_code	Method	Date	% Sample Used	T_Taxa	#Ind	MMI	Status
Powder River 1	YL_SPW1Q	EMAP_Targeted Riffle (8 comp)	07/11/2005	66.67	26	597	57.0	Non-Impaired
Powder River 1	YL_SPW1q	EMAP_Reach-wide	07/11/2005	100	28	296	58.1	Non-Impaired
Powder River 2	YL_SPW2Q	EMAP_Targeted Riffle (8 comp)	07/11/2005	50	26	613	52.3	Non-Impaired
Powder River 2	YL_SPW2q	EMAP_Reach-wide	07/11/2005	100	25	257	45.5	Non-Impaired
Powder River 3	YL_SPW3Q	EMAP_Targeted Riffle (8 comp)	07/11/2005	100	25	235	60.2	Non-Impaired
Powder River 3	YL_SPW3q	EMAP_Reach-wide	07/11/2005	100	19	234	46.4	Non-Impaired
Powder River 6	YL_SPW6Q	EMAP_Targeted Riffle (8 comp)	07/12/2005	100	19	224	49.0	Non-Impaired
Powder River 6	YL_SPW6q	EMAP_Reach-wide	07/12/2005	100	23	265	57.3	Non-Impaired
Powder River 5	YL_SPW5Q	EMAP_Targeted Riffle (8 comp)	07/12/2005	100	23	426	60.5	Non-Impaired
Powder River 5	YL_SPW5q	EMAP_Reach-wide	07/12/2005	100	20	261	65.4	Non-Impaired

(Figure 18. Impairment thresholds are lines at 0.8 (O/E) and 37 (MMI)).

The Bloom Creek site had 22 macroinvertebrate taxa and was dominated by highly tolerant organisms with a Montana biotic index of 8.21 and an old DEQ metric score of 11 of 24 (Bukantis 1998), which indicates moderate impairment. This site was highly impacted by cattle intrusions into the stream channel and riparian zone, as indicated by low Habitat Quality Index scores (12 on the BLM index, and 137 on the EPA index).

Summary of Aquatic Surveys

Three conclusions emerge from the sampling and analysis:

- Sturgeon chubs are obviously declining. Patton et al. (1998) found sturgeon chubs at half of the eight sites sampled in the Wyoming portions of the Powder River, while Confluence Consulting (2004) found sturgeon chubs in 2002 at only 1 Wyoming site close to the Montana border. Neither we nor the USGS (2005) captured a single sturgeon chub within 40 miles of the Wyoming border despite sampling 6 reaches. The rarity of the sturgeon chub is alarming for a river that is supposed to provide the most substantial habitat for this species (Hubert 1993, Patton et al. 1998). We recommend additional work on the distributional status and tolerance to water chemistry changes of the sturgeon chub and the Species of Concern mayflies as a component of any biomonitoring approach for CBM development in the immediate Powder River basin.

- All sites of the Powder River within the Middle Powder subbasin ranked unimpaired using the MMI, but by incorporating the fish O/E and habitat scores, a clearer determination of biological integrity can be made. Fish O/E analysis ranked Site 6 as impaired and Site 2 as borderline impaired, but taking all data into account, including the presence of 3 of 5 Species of Concern mayflies, best professional judgment would support moving Site 2 into the unimpaired category. Community integrity results from the fish, habitat and macroinvertebrate surveys combined to rank the Powder River reach upstream of Rough Creek (Site 5) as the most biologically intact,

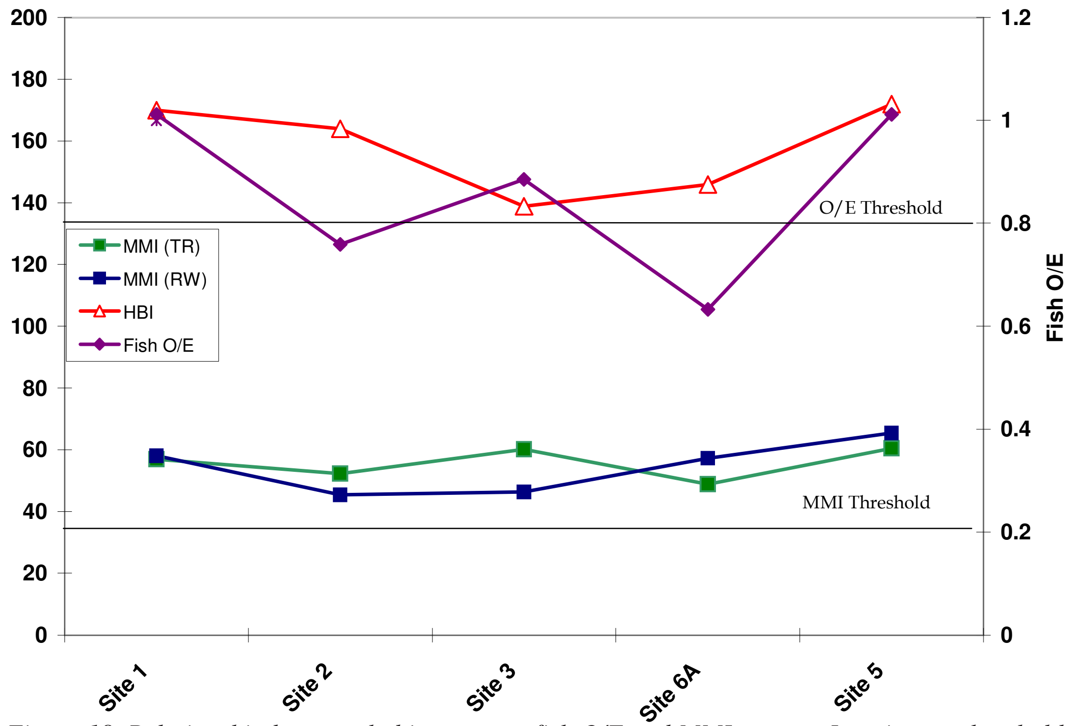


Figure 18. Relationship between habitat scores, fish O/E and MMI scores. Impairment thresholds are lines at .8 (O/e) and 37 (MMI).

followed by the Powder River reach at the Wyoming border (Site 1) and the Dry Creek reach, Site 2. We recommend choosing these as future monitoring sites.

- Macroinvertebrate samples show that the EMAP Targeted Riffle samples produce more taxa and numbers, track the fish O/E closer, are more consistent across sites and are an easily repeatable protocol for less variability in field operations. Therefore, we recommend the EMAP Targeted-Riffle Protocols for future monitoring efforts.

Relationship Between Broad-scale and Fine-scale Assessments

The broad-scale assessments, vegetation rapid assessment and aquatic condition surveys showed similar trends. HUC 060, the site closest to the Wyoming border and furthest from Broadus appears to be the most ecologically unimpaired watershed in the subbasin, probably because it has fewer development pressures than more northern sites. HUC 090, the most populated and developed, shows effects of multiple impacts at several locations.

It is useful to distinguish between cumulative impacts and cumulative effects (Johnson 2005). Broad-scale assessments look at impacts, i.e. the activities and events that change natural conditions, while fine-scale assessments examine the results of those impacts. In the Middle Powder subbasin, for example, water diversions and impoundments are impacts, while dewatering of streams or loss of species are effects. Impacts may occur at a significance distance from their effects, as is often the case with upstream-downstream relationships observed in aquatic systems, or they may occur in close proximity. For example, impacts from land use activities in upstream HUCs may have effects downstream, with the biological integrity of aquatic survey site 6 being characterized as "impaired." On the other hand, the higher population density, greater percentage of agricultural use, and increased movement of machinery associated with agriculture may lead to a relatively localized spread of noxious weeds and exotic species.

The value of watershed-level assessments lies in identifying areas where impacts are currently occurring, rather than merely seeking out effects that have already occurred. By combining both site-level and watershed-level assessments, it is possible to select areas where management can make a substantial difference in future wetland and aquatic health. Thus, even when there are similar findings between the two levels of assessment, they need to be examined less for correlation than for the different perspectives they provide.

Management Opportunities

The BLM owns and administers a substantial proportion of land within the study area, and can play an important role in conserving or restoring natural functioning. Based on our broad-scale and fine–scale assessments, and our observations in the field, we have identified several specific management opportunities.

Conservation of Aquatic Resources

As discussed above, the Powder River, one of the last undammed large prairie rivers in the United States, represents the sole remnant of a once widespread Great Plains riverine community of fish and invertebrates (Hubert 1993). The Middle Powder subbasin alone supports 19 Montana native fish species and numerous species of rare invertebrates. Because of the water quality concerns that have been raised in connection with CBM development, we specifically recommend additional work on the distribution and water chemistry tolerances of the sturgeon chub and the Species of Concern mayflies. We also recommend that these species be included as a component of any biomonitoring approach during CBM development in the immediate Powder River basin.

Invasive Species

Many of the exotic species that were observed in the Powder River corridor and tributary riparian areas are not considered noxious (e.g. smooth brome, crested wheatgrass, cheatgrass). However, we did see several stands of leafy spurge, mostly in riparian areas and wet draws, and salt cedar and Russian olive were common, if not abundant, along the Powder River corridor. Russian olive and salt cedar can dominate riparian woody vegetation with potentially dire consequences for future habitat (Kudray and Cooper 2004) if education followed by control is not successful. Results of weed sampling indicate that knapweeds have also gained a foothold in the subbasin. Because the Middle Powder is relatively isolated, the spread of weeds is primarily water-driven, although the prevalence of leafy spurge in the more populated HUCs suggests that agricultural and transportation activities may also be vectors. As CBM development begins, road-building and equipment movement between sites will greatly facilitate noxious weed transport. Vigilant monitoring by BLM staff, permittees and leaseholders will be necessary to prevent incursions of noxious weeds into weed-free parts of the watershed and to minimize weed-driven loss of range forage and riparian plant communities.

Grazing Management

Grazing pressure was generally light to moderate throughout the subbasin, but as we noted, the dry winter of 2005 prompted several ranchers in the area to reduce herds, and the June rains produced substantial growth across the range. However, our field surveys led us to conclude that the generally good condition of the range in the subbasin was not merely a short-term effect, but rather reflected good grazing management in some areas and a lack of water in others. However, riparian vegetation represents an especially attractive resource for cattle, and the shade that riparian trees provide is attractive during all hot summer days. Insufficient data exists to conclude that the lack of regeneration of cottonwoods in the Middle Powder is attributable to cattle, especially given the hydrologic changes that have occurred over the past few decades. Nonetheless, cattle grazing is certainly detrimental to seedling establishment and growth (Samuelson and Rood 2004), and so we recommend that grazing management plans incorporate recognition of the effects grazing on riparian integrity. The two watersheds with the highest scores on the Riparian Grazing Threat Index, HUC 060 and 070, also have the highest percentage of public ownership, thus providing an integrated management opportunity. We observed that many permittees in these watersheds already had off-stream watering facilities for their cattle, and that nutrient feeders and salt blocks were also placed in upland areas. These management practices, coupled with frequent utilization monitoring, and the use of physical barriers where necessary, will help ensure that the high-quality riparian resources remain intact and that impaired resources have the opportunity to recover.

Watershed-specific Management Efforts

HUCs 060 and 070 have the highest scores on our Composite Watershed Condition index, and as noted above, have a high percentage of public ownership (65% and 39%, respectively). Whether or not public ownership puts them more at risk for CBM development than adjacent watersheds with more private ownership remains to be seen, given other factors like access, power, and a stable labor force. However, because of their location, the Powder River corridor portions of these watersheds are already at risk from existing and future CBM activities in Wyoming. Increased salinity and SAR levels have already been identified as a source of potential harm to the aquatic community (USDI and State of Montana 2003), and the shift in fish species composition identified in our aquatic surveys raises concerns that water quality and quantity may be deteriorating. We recommend that these two watersheds be prioritized for monitoring and management. This does not suggest that management should be focused only on this watershed, but rather that placing a high priority on maintaining habitat conditions in the healthiest watersheds is a sound management approach.

We also note that the watershed with the lowest score on the Composite Watershed Condition Index (HUC 090) has the highest percentage of private ownership. Because the CWCI reflects overall land use within the watersheds, it should not be taken as an indication that public lands within these areas are in poor condition. Instead, this score might be seen as a warning to public land managers that circumstances beyond their control may be threatening the integrity of the lands they manage, and that these lands, too, deserve prioritized attention.

Protection of Riparian Habitat

Roads, agriculture, grazing, and water withdrawals all appear to be affecting the riparian vegetation of the subbasin. The close proximity of roads to the majority of tributaries in the Middle Powder limits the width of the riparian corridor, increases sedimentation, and potentially introduces invasives. Properly planning and implementing road establishment, maintenance, and closures will reduce negative impacts on riparian habitat.

We noted above that grazing management is one approach to protecting seedlings and young trees, and likely would be effective for shrub restoration. However, cottonwood establishment requires floods of sufficient magnitude to create suitable substrate above the ice-scour zone, which apparently has not happened for decades since we observed no young cottonwoods. Since the Powder River is undammed there is the potential to investigate and restore hydrology that would be suitable for cottonwood establishment.

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Appendix A. Global/State Rank Definitions

Heritage Program Ranks

The international network of Natural Heritage Programs employs a standardized ranking system to denote global (range-wide) and state status. Species are assigned numeric ranks ranging from 1 to 5, reflecting the relative degree to which they are "at-risk". Rank definitions are given below. A number of factors are considered in assigning ranks — the number, size and distribution of known "occurrences" or populations, population trends (if known), habitat sensitivity, and threat. Factors in a species' life history that make it especially vulnerable are also considered (e.g., dependence on a specific pollinator).

Global Rank Definitions (NatureServe 2003)

G1	Critically imperiled because of extreme rarity and/or other factors making it highly vulnerable to extinction
G2	Imperiled because of rarity and/or other factors making it vulnerable to extinction
G3	Vulnerable because of rarity or restricted range and/or other factors, even though it may be abundant at some of its locations
G4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery
G5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery
T1-5	**Infraspecific Taxon** (trinomial) —The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank

State Rank Definitions

S1	At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to extirpation in the state
S2	At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to extirpation in the state
S3	Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas
S4	Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern
S5	Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range

Combination Ranks

G#G# or S#S#	**Range Rank**—A numeric range rank (e.g., G2G3) used to indicate uncertainty about the exact status of a taxon

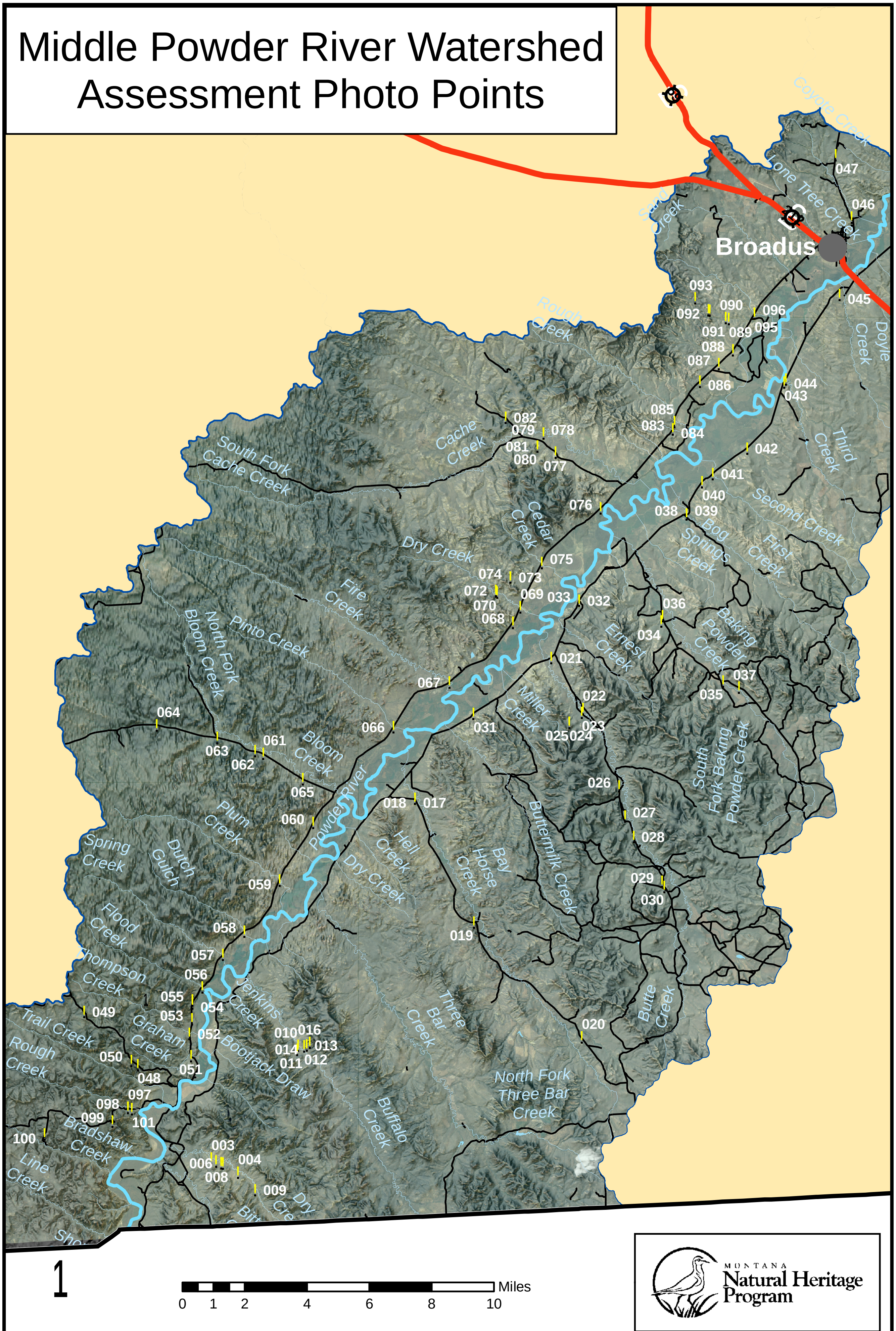
Qualifiers

NR	Not ranked
Q	**Questionable taxonomy that may reduce conservation priority**—Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank

X	**Presumed Extinct**—Species believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered
H	**Possibly Extinct**—Species known from only historical occurrences, but may never-the-less still be extant; further searching needed
U	**Unrankable**—Species currently unrankable due to lack of information or due to substantially conflicting information about status or trends
HYB	**Hybrid**—Entity not ranked because it represents an interspecific hybrid and not a species
?	**Inexact Numeric Rank**—Denotes inexact numeric rank
C	**Captive or Cultivated Only**—Species at present is extant only in captivity or cultivation, or as a reintroduced population not yet established
A	**Accidental**—Species is accidental or casual in Montana, in other words, infrequent and outside usual range. Includes species (usually birds or butterflies) recorded once or only a few times at a location. A few of these species may have bred on the one or two occasions they were recorded
Z	**Zero Occurrences**—Species is present but lacking practical conservation concern in Montana because there are no definable occurrences, although the taxon is native and appears regularly in Montana
P	**Potential**—Potential that species occurs in Montana but no extant or historic occurrences are accepted
R	**Reported**—Species reported in Montana but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program has not yet received first-hand information; others are old, obscure reports
SYN	**Synonym**—Species reported as occurring in Montana, but the Montana Natural Heritage Program does not recognize the taxon; therefore the species is not assigned a rank
*	A rank has been assigned and is under review. Contact the Montana Natural Heritage Program for assigned rank
B	**Breeding**—Rank refers to the breeding population of the species in Montana
N	**Nonbreeding**—Rank refers to the non-breeding population of the species in Montana

Appendix B. Site Descriptions and Photographs from Riparian, Wetland, and Upland Vegetation Surveys

Middle Powder River Watershed Assessment Photo Points

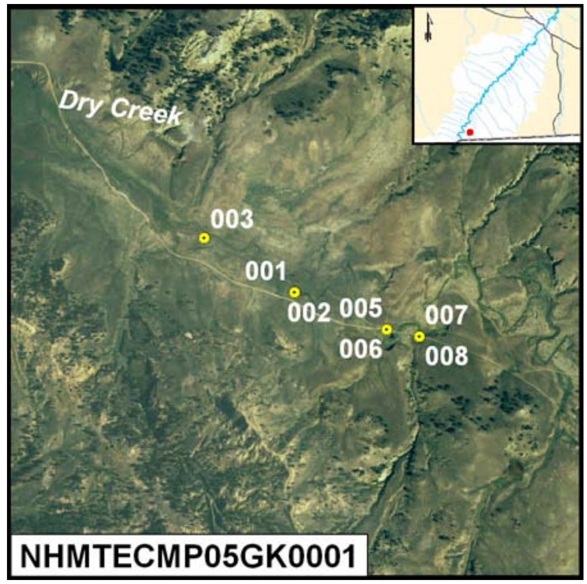


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0001
Photo Date: 8/26/2005

Photo Point Description

Dead cottonwood near Dry Creek and 2-track intersection. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

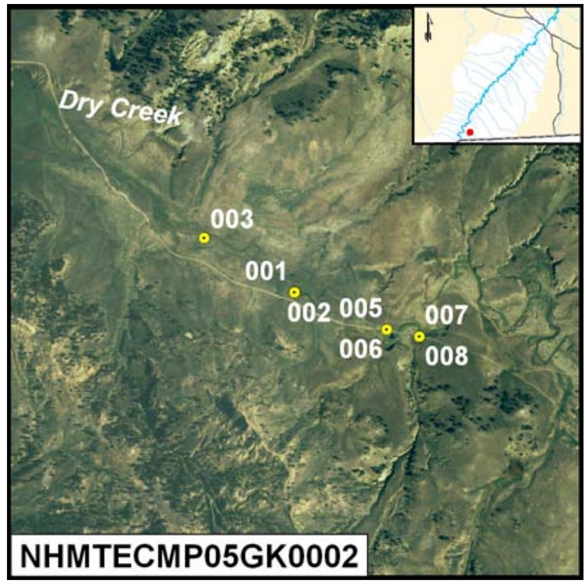


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0002
Photo Date: 8/26/2005

Photo Point Description

Great plains toad (probably) in pool of Dry Creek. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

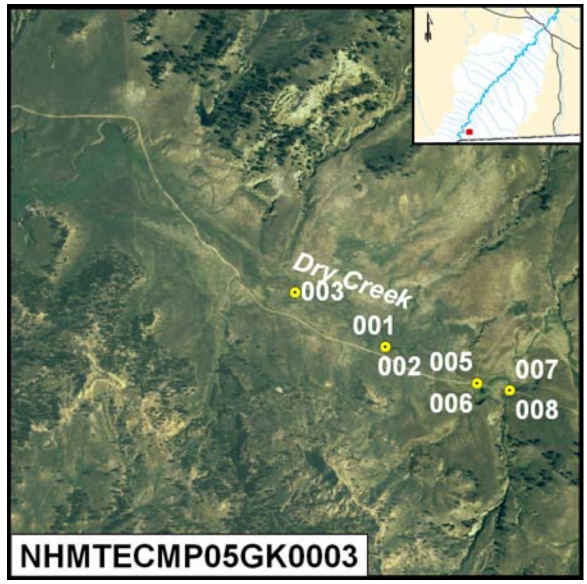


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0003

Photo Date: 8/26/2005

Photo Point Description



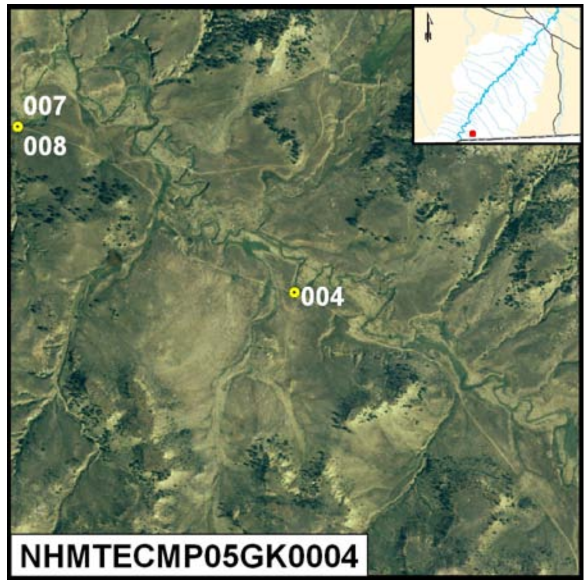
Upstream view from GPS point. Recent rains. Some incised areas here and also wider W. wheatgrass flats. Silver sage is common. Prairie dog activity nearby. A couple scattered cottonwood trees. Patches of rose, Ribes, and snowberry along north facing stream banks. Generally bank stability is good. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

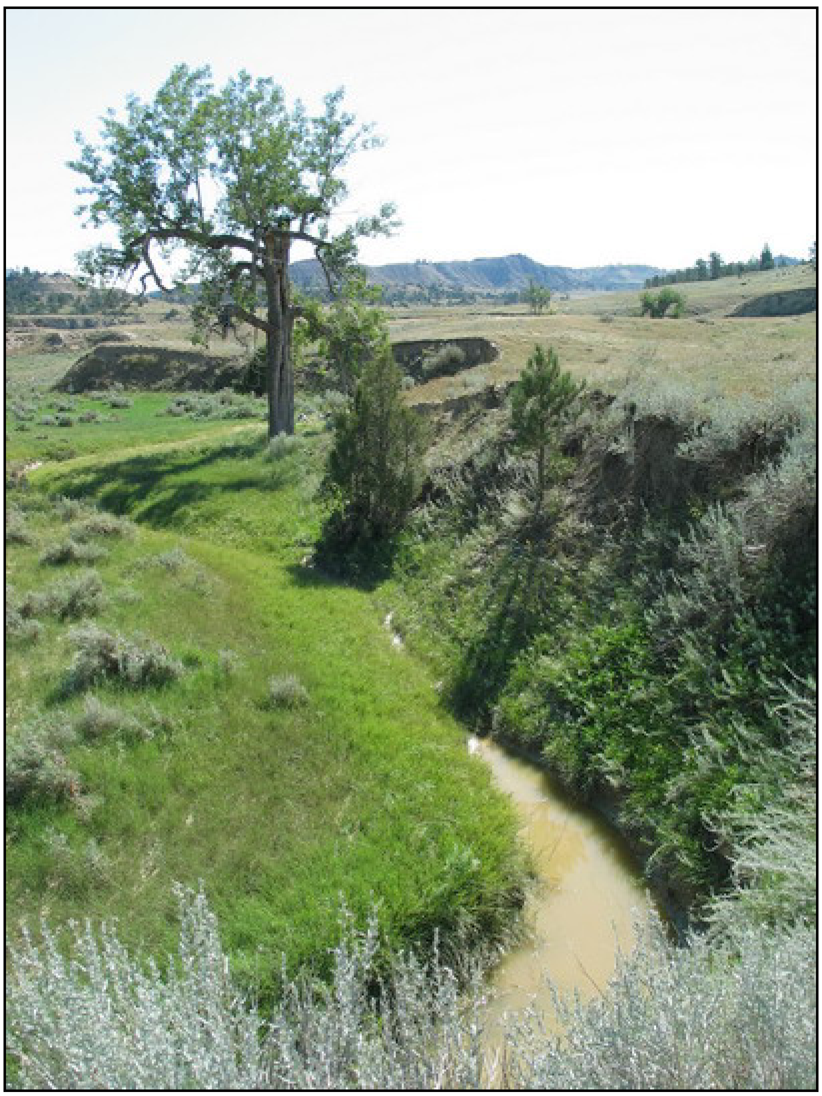
Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0004
Photo Date: 8/26/2005

Photo Point Description

Steep north facing bank with shrubs, pine and juniper establishment. Decadent cottonwood. Sage is most common on floodplain, which is up to 40' wide. Valley bottom uplands are a mix of W. wheatgrass and blue grama.





Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0005
Photo Date: 8/26/2005

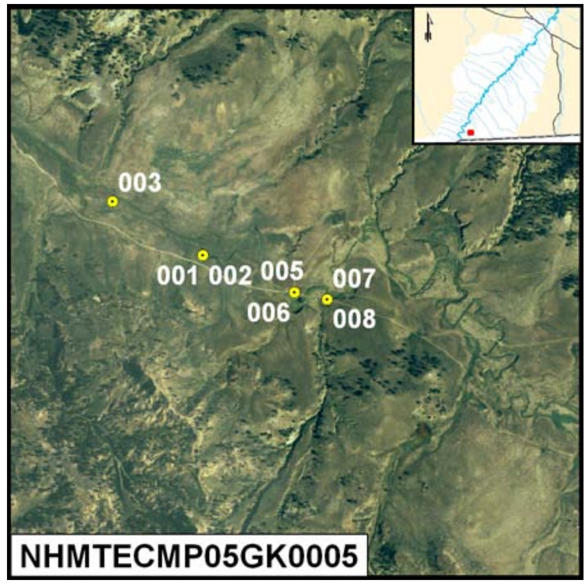


Photo Point Description

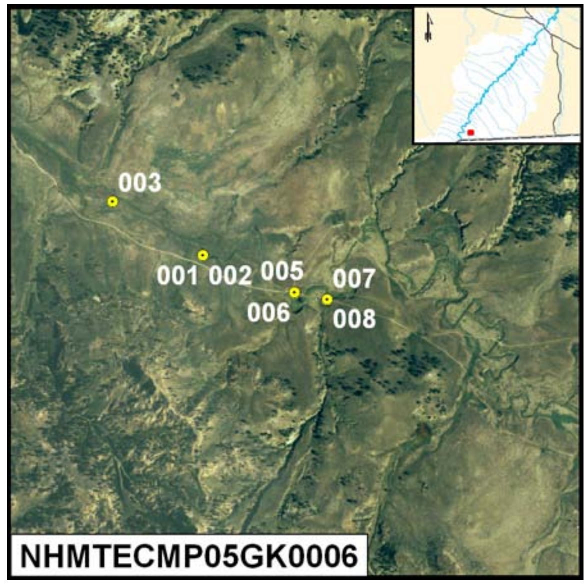
Photo of section line 21 - 28 crossing Dry Creek. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0006
Photo Date: 8/26/2005

Photo Point Description

Photo of section line 21 - 28 crossing Dry Creek. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

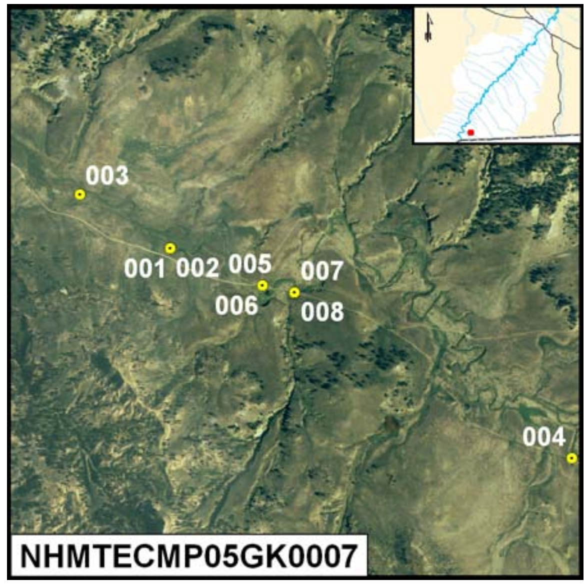


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0007
Photo Date: 8/26/2005

Photo Point Description

Moderately incised Dry Creek. Location is approximate. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

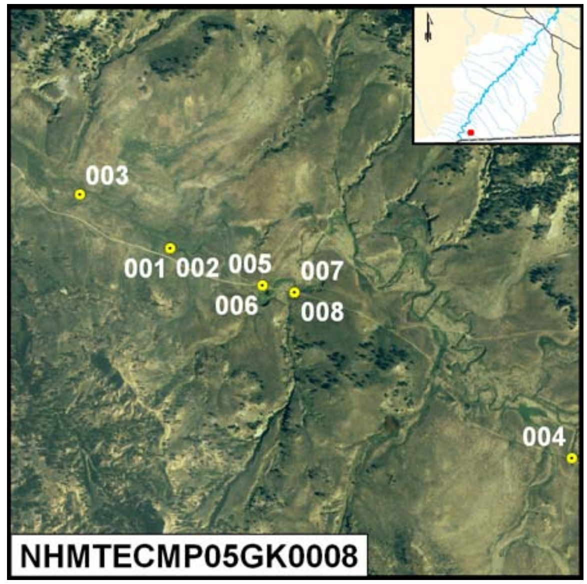


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0008
Photo Date: 8/26/2005

Photo Point Description

Side channel off Dry Creek with conifer vegetation. Location is approximate. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0009
Photo Date: 8/26/2005

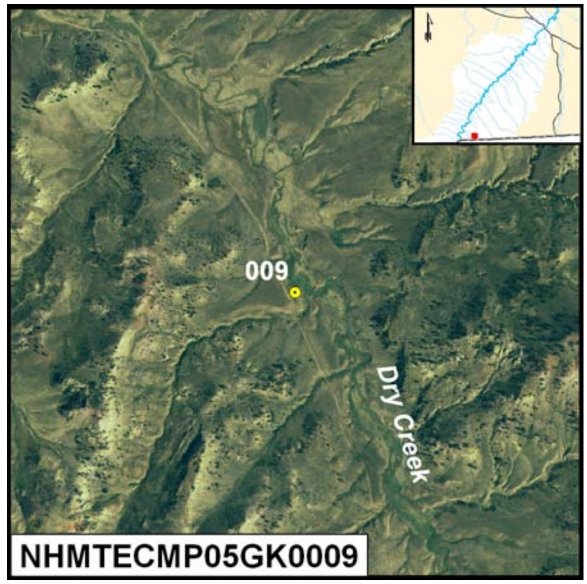


Photo Point Description

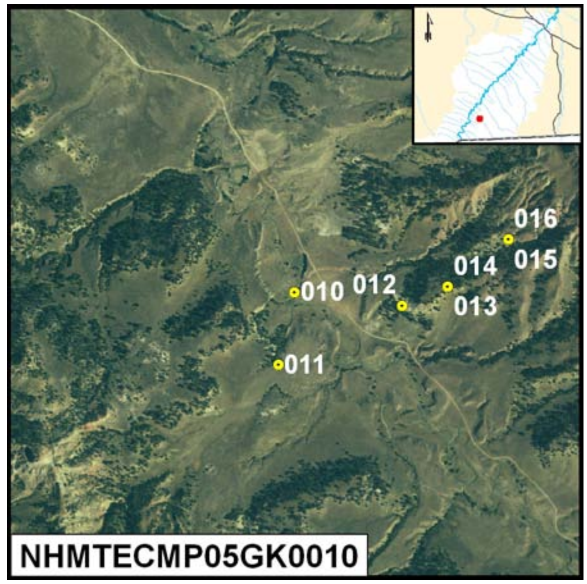
Approximate area of section line 27 - 34 looking north across stream crossing. Uplands in Dry Creek valley bottom are mostly W. wheatgrass and blue grama. Forbs are not very common, some prickly pear, fringed sage, and rosy pussytoes. Wyoming sage is common but not dense, silver sage is in lower areas. Some needle and thread - patchy. Areas soil typed as Ponderosa Pine have been mostly burned off but young trees are common. Bluebunch is common as soon as there are slopes, sandstone outcrops have common sideoats grama. Small drainages higher on the landscape are often deeply gullied (10' or more). Siltstone is common. Some threadleaf sedge on eroded slopes. Saltbush is common, soapweed yucca and prairie sandreed occur in sandy spots. Slopes become very bare with southern exposures and/or steepness.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0010
Photo Date: 8/26/2005

Photo Point Description

Photo looks downstream from GPS point. Junipers are fairly common along stream floodplain, further downstream there are considerable stringers of cottonwood and other hardwoods although not visited (private land). This area shows considerable cattle use and lower bank stability.

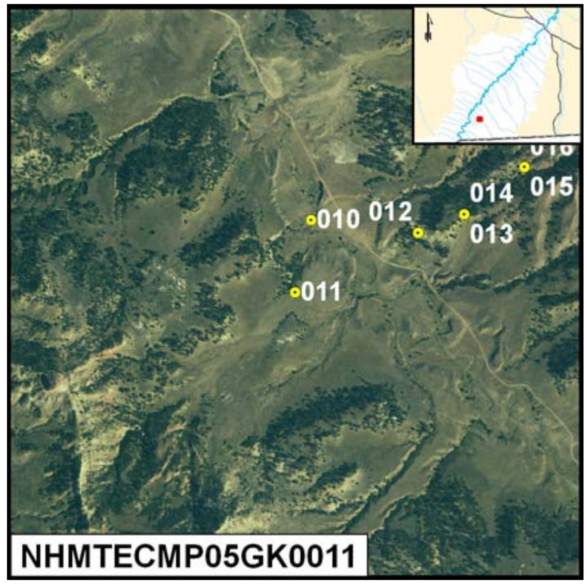


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0011
Photo Date: 8/26/2005

Photo Point Description

Secondary tribs have deep gullies, typically with conifers and no water. Uplands are similar to other areas with W. wheatgrass, blue grama, and a mix of silver and Wyoming sage. This area seems to have been heavily grazed based on the blue grama lawns here.

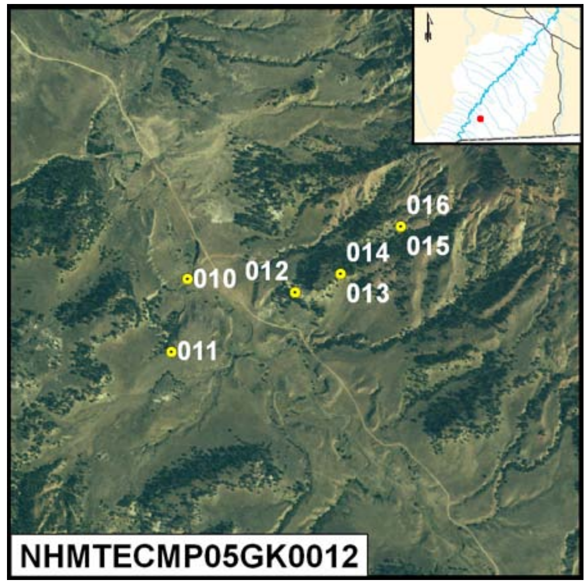


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0012
Photo Date: 8/26/2005

Photo Point Description

Photo looks north toward south facing slopes with sandstone outcrops. Immediate lower slopes have a mix of pine and juniper with sparse groundcover, some bluebunch, threadleaf sedge and sideoats grama, fairly heavy litter. Steep hillsides have scattered bluebunch and broom snakeweed.

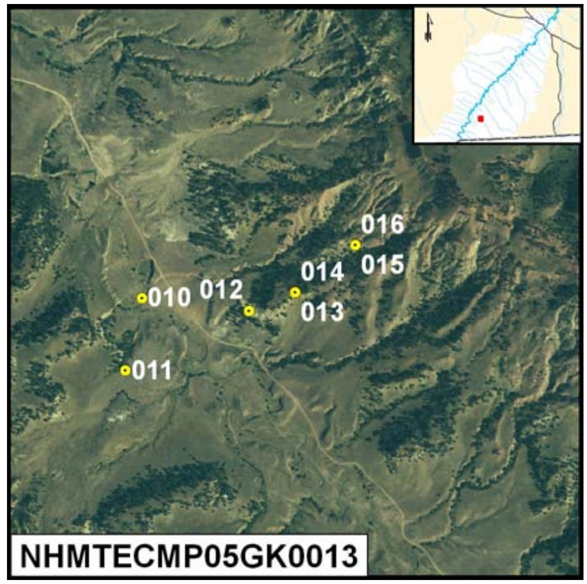


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0013
Photo Date: 8/26/2005

Photo Point Description

Top of sandstone bluff with threadleaf sedge dominant with sideoats grama, bluebunch, Wyoming sage, and soapweed yucca. Elsewhere there are some treeless patches with fairly heavy bluebunch.

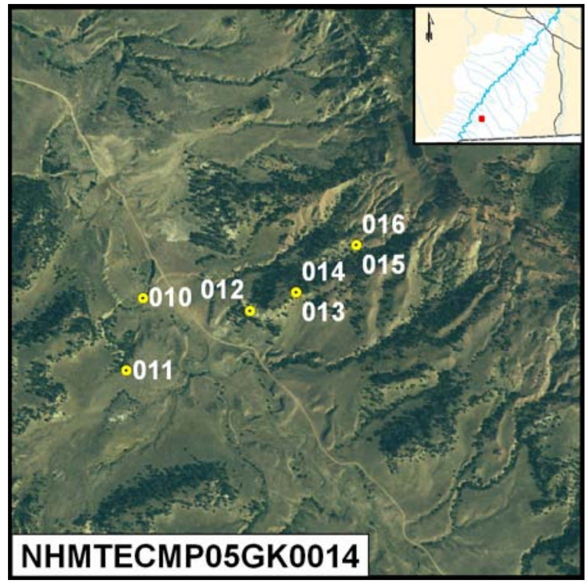


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0014
Photo Date: 8/26/2005

Photo Point Description

View south across Buffalo River valley

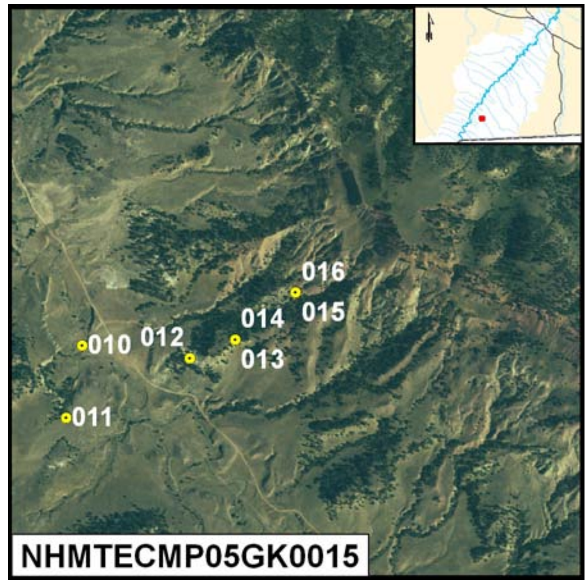


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0015
Photo Date: 8/26/2005

Photo Point Description

Sparsely vegetated steep hillside. Benches have heavier bluebunch. Shrubs are the dominant vegetation on these steep slopes: wyoming sage, saltbush, and greasewood are typical. Steep slopes have layer of shaley siltstone. Location is approximate.

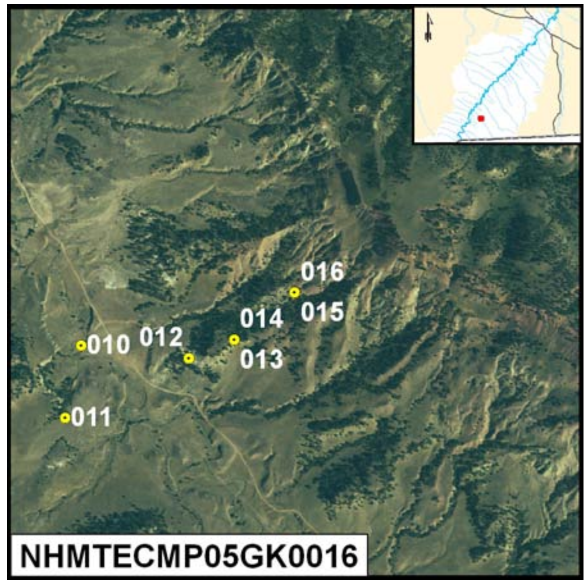


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0016
Photo Date: 8/26/2005

Photo Point Description

Sparsely vegetated steep hillside. Location is approximate. Benches have heavier bluebunch. Shrubs are the dominant vegetation on these steep slopes: wyoming sage, saltbush, and greasewood are typical. Steep slopes have layer of shaley siltstone.

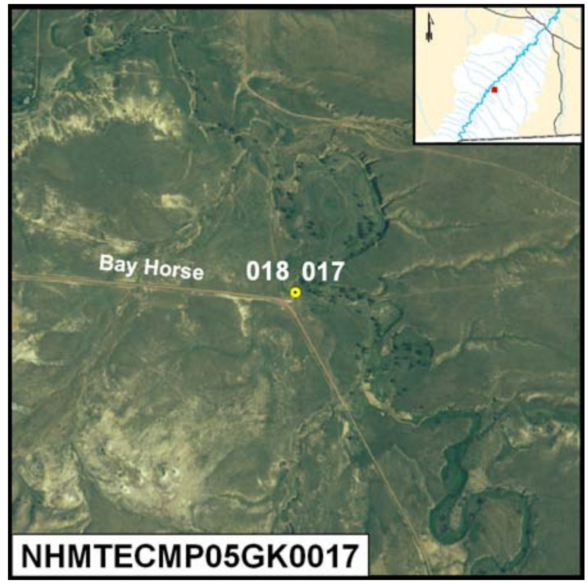


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0017
Photo Date: 8/26/2005

Photo Point Description

Decadent but common cottonwood along lower creek. Location is approximate.

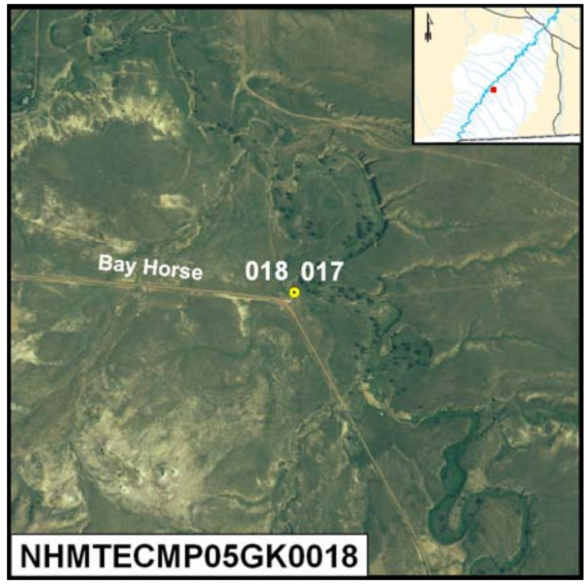


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0018
Photo Date: 8/26/2005

Photo Point Description

Wetland area within 40' wide floodplain. Location is approximate. Surrounding hills are relatively low and valley is broad, quite different from some of the sub-watersheds within the Middle Powder watershed.

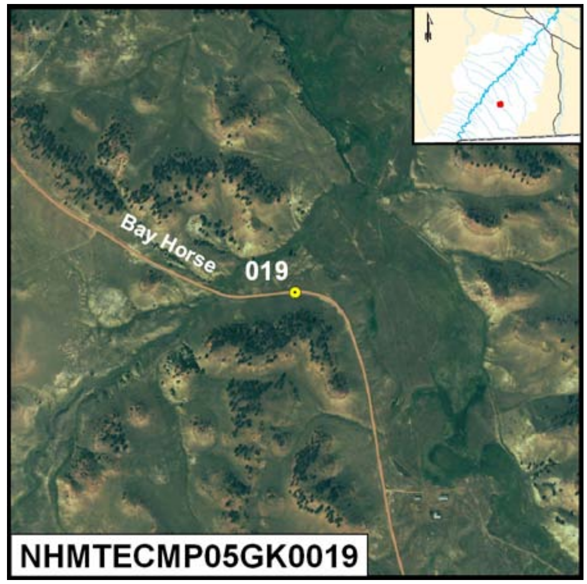


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0019
Photo Date: 8/26/2005

Photo Point Description

Typical valley bottom area for this watershed about 5 miles up. Quite broad and looks productive. Scattered cottonwoods in riparian areas but less trees and gentler topography than some other watersheds..

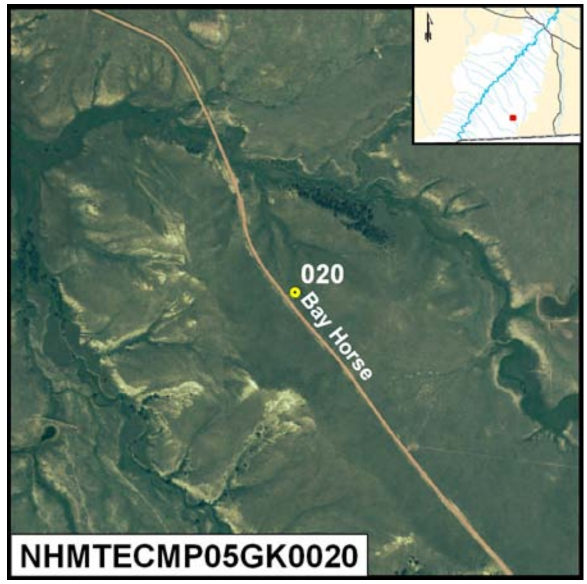


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0020
Photo Date: 8/26/2005

Photo Point Description

Hay cutting with continued riparian cottonwood areas. This is far up the valley. Location is approximate.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0021
Photo Date: 8/27/2005

Photo Point Description

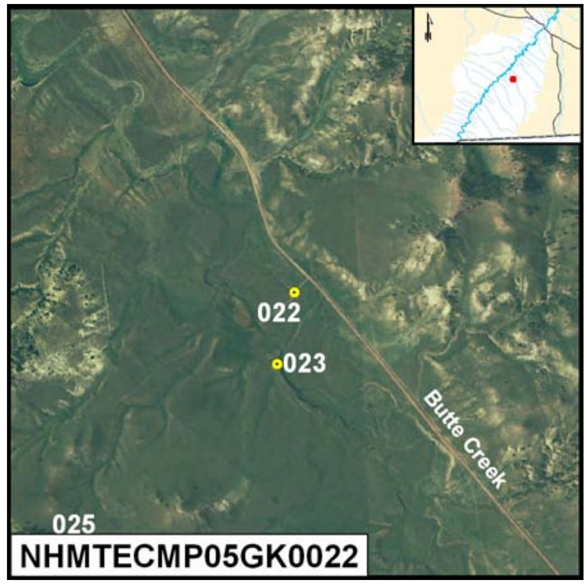
Decadent cottonwood

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0022
Photo Date: 8/27/2005

Photo Point Description

View downstream on state land. Scattered junipers along mostly south bank of creek. Streambed in good shape, well vegetated. Some remnants of dead cottonwood and one still living upstream. Floodplain about 30' wide.

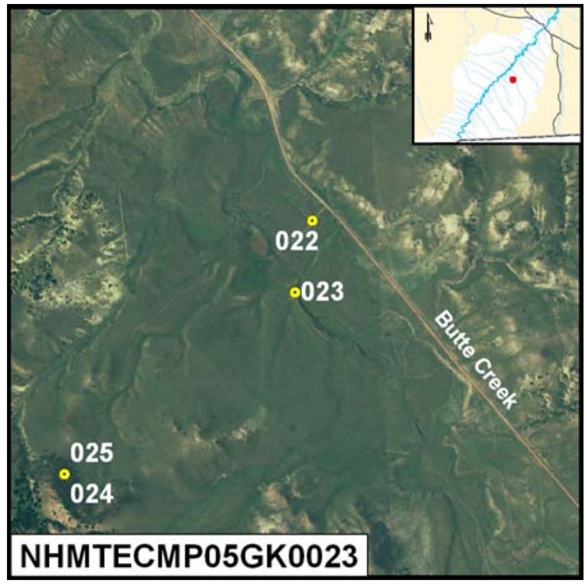


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0023
Photo Date: 8/27/2005

Photo Point Description

Stream cut bluff with scattered trees. Cheatgrass and Japanese brome common here. Topography is gentle, higher areas have trees common but often only in patches or scattered. Some steep exposed slopes. Uplands in valley bottom have common needle and thread, blue grama, Japanese brome, and fringed sage. W. wheatgrass is a minor component typically but dominant in some patches. Low grassland hills have needle and thread, sideoats grama, threadleaf sedge, soapweed yucca, and bluebunch.

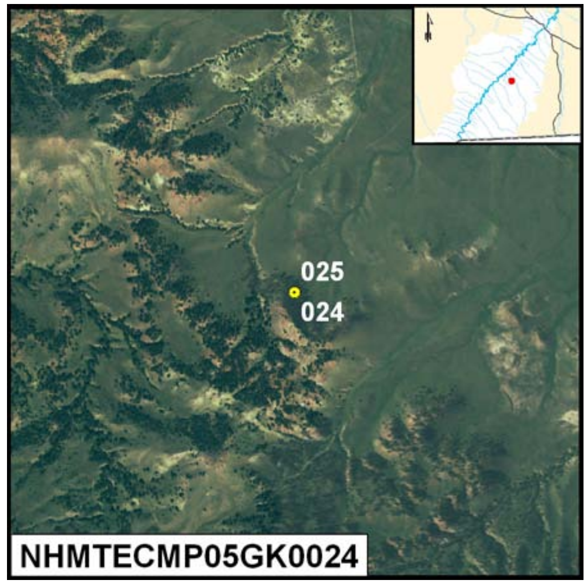


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0024
Photo Date: 8/27/2005

Photo Point Description

Photo is from toeslope looking into stand, gps point is in stand. Mostly juniper but pine is common. Toeslope was quite lush with same needle and thread mix as elsewhere. Cheatgrass and Japanese brome are common throughout. Grass cover under trees is sparse, sideoats grama is most common, but prairie junegrass and bluebunch are also common. Gravel and larger rock are dominant on surface (mudstone). Even though sandy species are common in the valley bottom, this area has no noticeable sandstone outcrops.

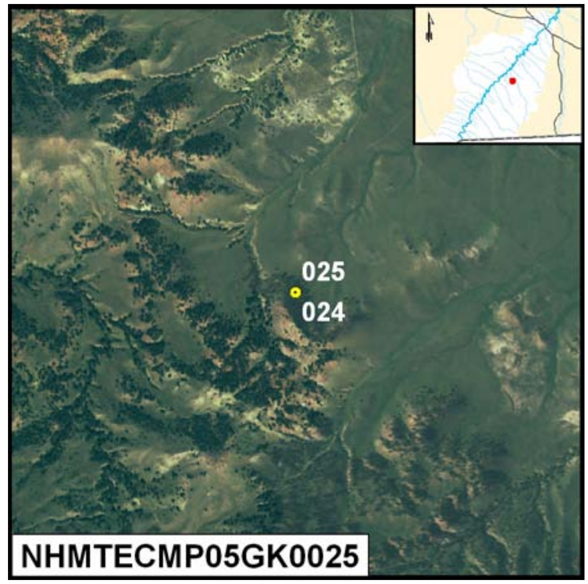


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0025
Photo Date: 8/27/2005

Photo Point Description

View across valley to south facing slope. Sage is patchy here, little in valley bottom and silver sage only.

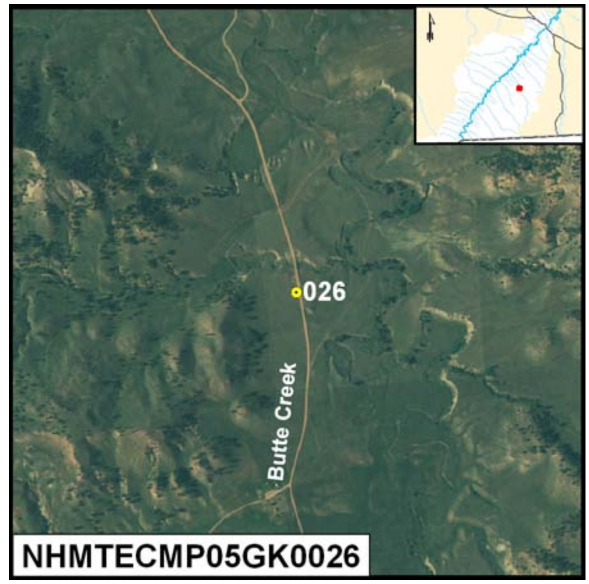


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0026
Photo Date: 8/27/2005

Photo Point Description

View of Butte Creek valley with cottonwoods, which are fairly common along the upper part of the creek. Junipers are also mixed in as are box elders and some other shrubs. View includes a tributary with hardwood extending up the draw.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0027
Photo Date: 8/27/2005

Photo Point Description

View up valley includes hardwood in main floodplain and tributary in background with hardwood draws, which are common in this part of the valley.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0028
Photo Date: 8/27/2005

Photo Point Description

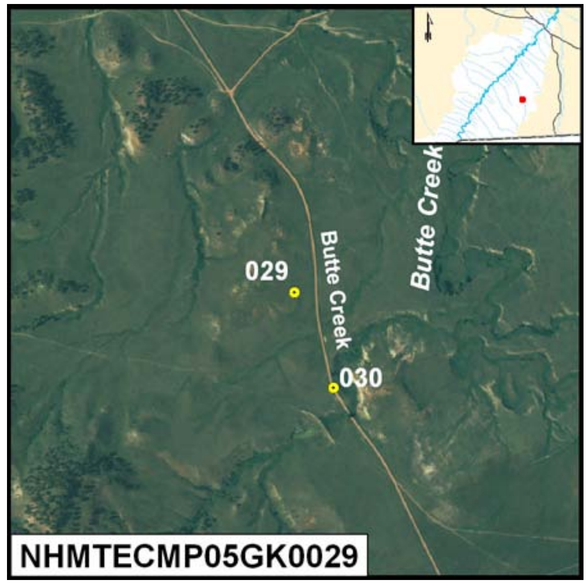
View up tributary with smaller shrubs. Even this upper part of the valley has sandier grassland species. Crested wheat is common in places.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0029
Photo Date: 8/27/2005

Photo Point Description

Needle and thread, blue grama grassland with Japanese brome common, more threadleaf sedge as slope increases. Patches of little bluestem are common.

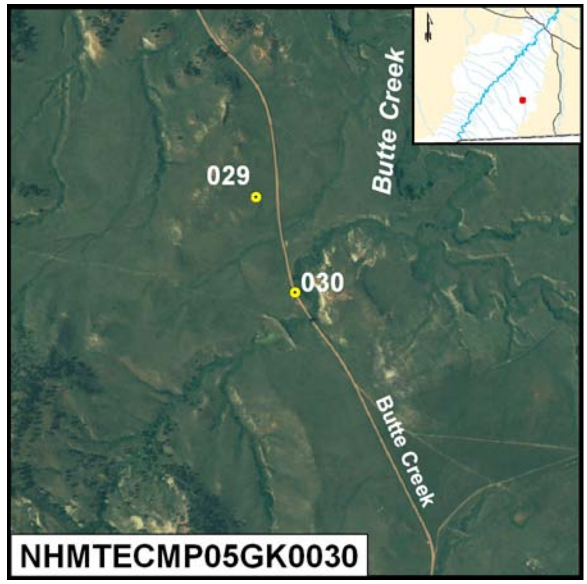


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0030
Photo Date: 8/27/2005

Photo Point Description

Tributary with plum, cherry, snowberry, rose, and silver sage. Some hay cutting up here. Rounded gentle hills with common pine.

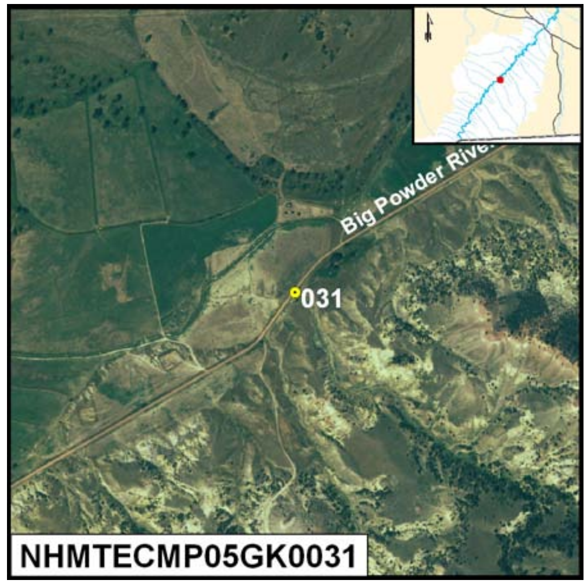


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0031
Photo Date: 8/27/2005

Photo Point Description

View up nice cottonwood stand going up Ernst Creek.
Approximate location.

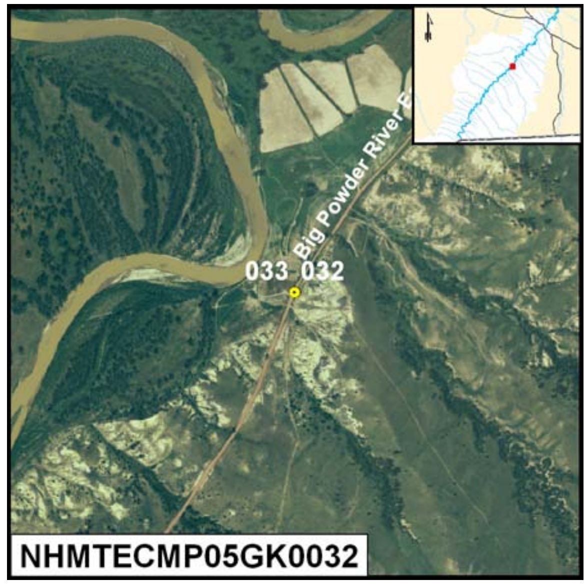


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0032
Photo Date: 8/27/2005

Photo Point Description

Russian olive infestation.

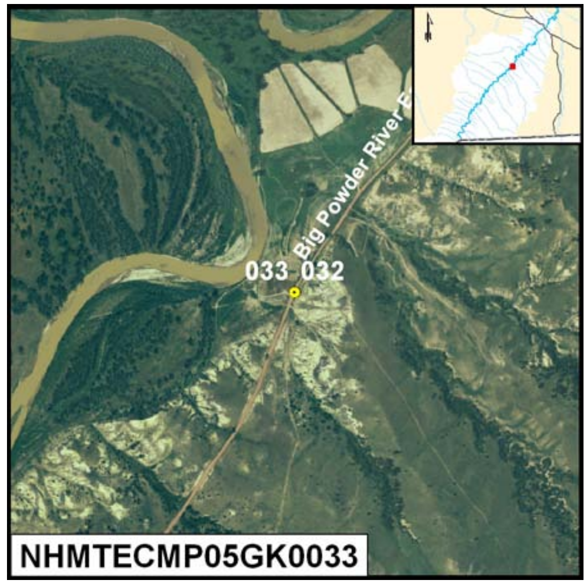


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0033
Photo Date: 8/27/2005

Photo Point Description

Russian olive infestation.

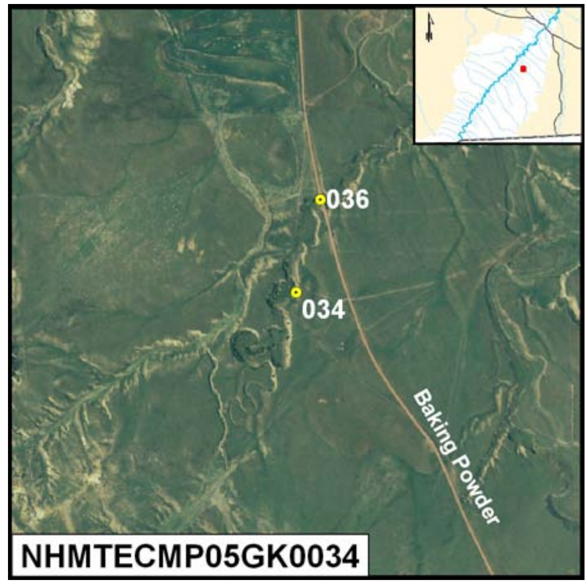


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0034
Photo Date: 8/27/2005

Photo Point Description

Further up tributary, juniper is common. Grasslands are mostly blue grama and W. wheatgrass with a mix of silver and Wyoming sage (common but not dense). Lower part of the valley is flat and broad with hay fields and much crested wheat.

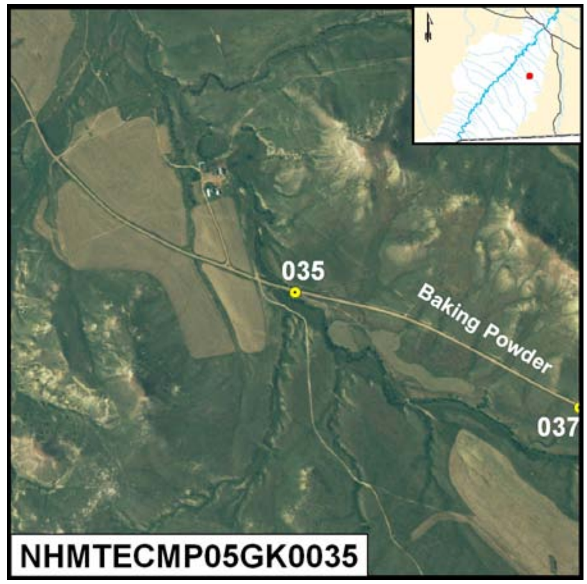


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0035
Photo Date: 8/27/2005

Photo Point Description

Baking Powder Creek. Cottonwoods and multi-layered shrubs start about here. Lower part of creek doesn't have these. Some steep and bare hills on the north side of the valley, other side is a bit gentler and more vegetated. Trees are patchy on both sides.

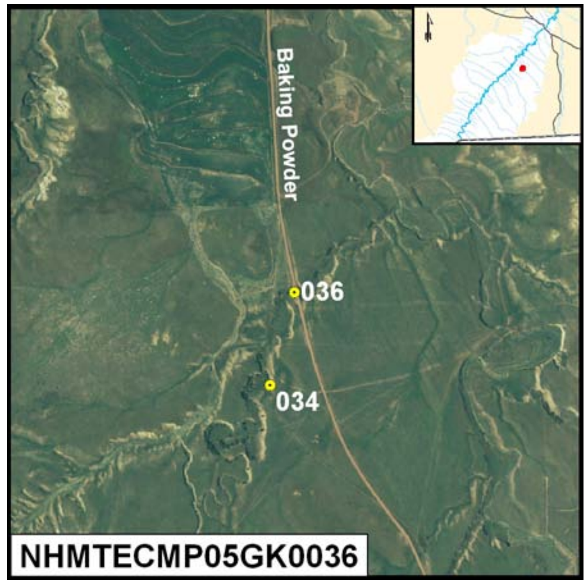


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0036
Photo Date: 8/27/2005

Photo Point Description

Shrubs and trees where the Baking Powder Creek crosses the road.

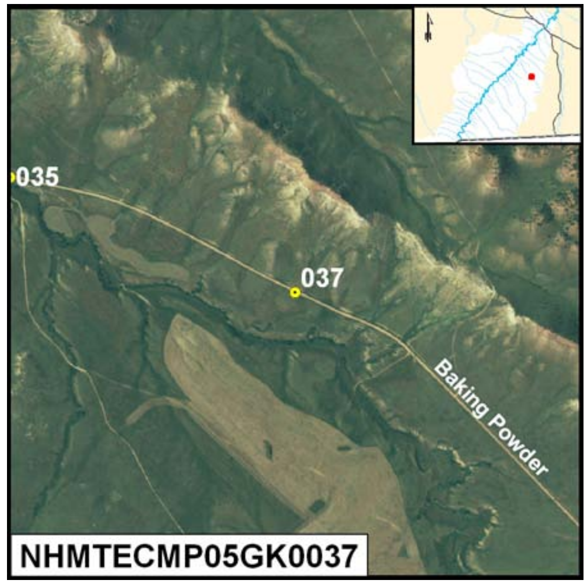


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0037
Photo Date: 8/27/2005

Photo Point Description

View of upper valley with cottonwood and other trees and shrubs along Baking Powder Creek and tributaries.

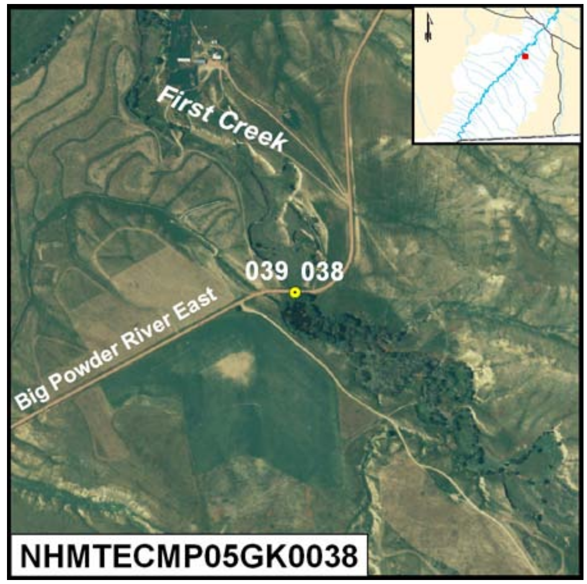


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0038
Photo Date: 8/27/2005

Photo Point Description

View from road down First Creek.

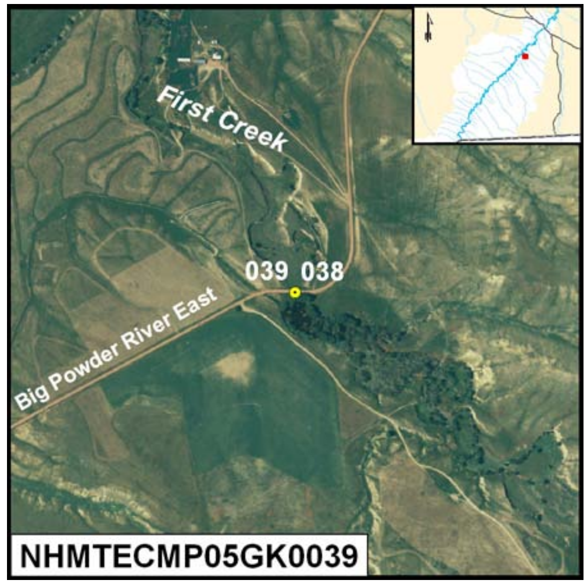


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0039
Photo Date: 8/27/2005

Photo Point Description

Upstream First Creek view with good band of cottonwoods.

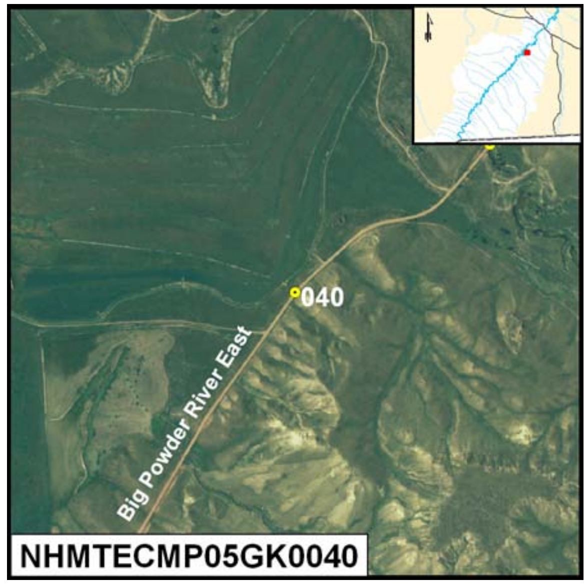


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0040
Photo Date: 8/27/2005

Photo Point Description

Large irrigated hay field.

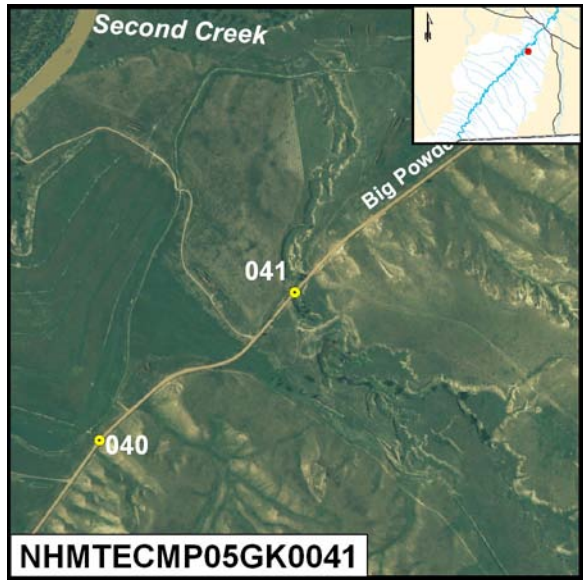


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0041
Photo Date: 8/27/2005

Photo Point Description

Second Creek. Scattered cottonwoods.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0042
Photo Date: 8/27/2005

Photo Point Description

This part of the valley is very broad and flat, only low hills in the distance.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0043
Photo Date: 8/27/2005

Photo Point Description

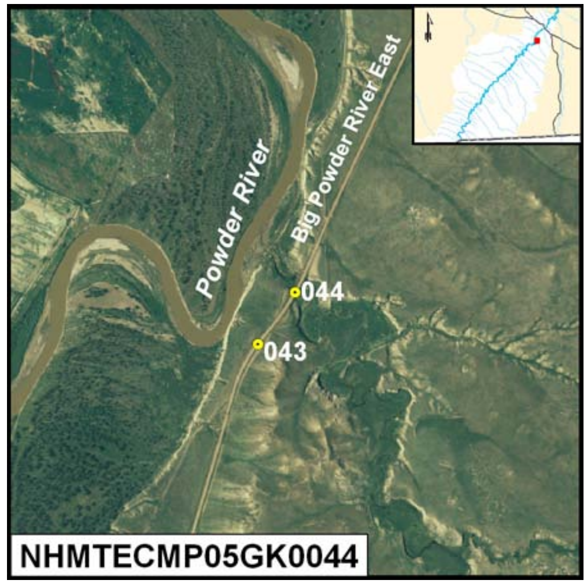
Decadent, dying and dead cottonwoods

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0044
Photo Date: 8/27/2005

Photo Point Description

View up Third Creek, area up road to no trespassing sign. South of here had heavy needle and thread cover.

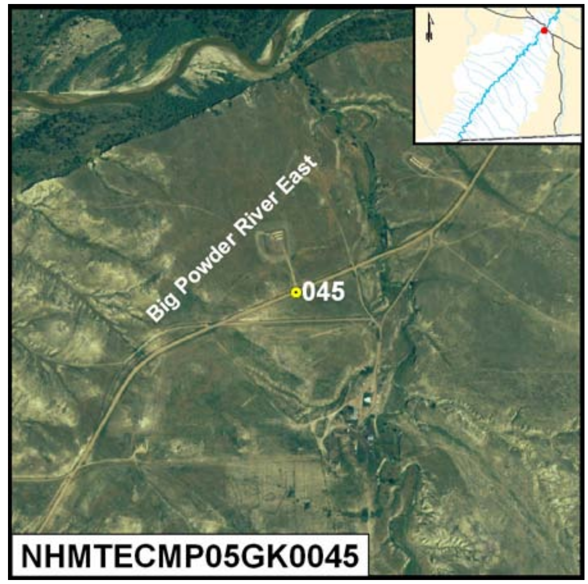


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0045
Photo Date: 8/27/2005

Photo Point Description

View up Doyle Creek with regular cottonwood stringers. Section 36, north of Broadus, is State land with blue grama, crested wheat, needle and thread, and sage.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0046
Photo Date: 8/27/2005

Photo Point Description

View up Coyote Creek. Scattered cottonwood, deep incisement here. Very minimal other woody development, cottonwood becomes more scattered until there is eventually none upstream.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0047
Photo Date: 8/27/2005

Photo Point Description

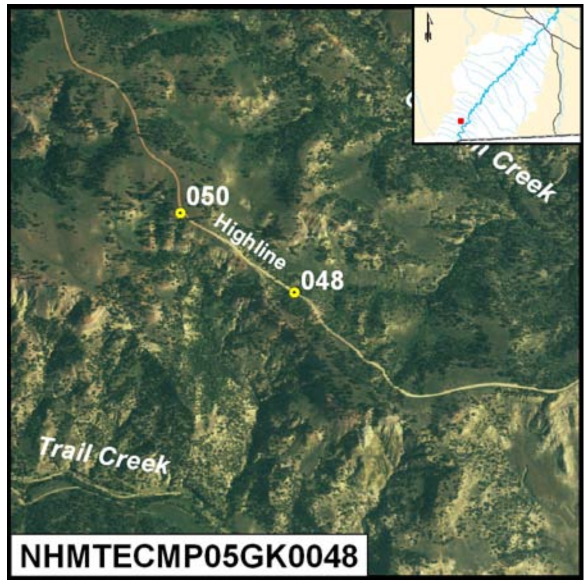
View of heavier Wyoming sage in this area, needle and thread is common throughout. Background is eroded hills with common tree patches (edge of watershed. Most of the watershed is low rolling hills with scattered steeper knobs. This subwatershed has sage as heavy as anywhere else in the Middle Powder watershed.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0048
Photo Date: 8/28/2005

Photo Point Description

Photo of upper Graham Creek. Steep hills go down to the Powder River with forest cover of pine and juniper fairly continuous. Bluebunch is the most common grass with fairly heavy sage in open areas that are not steeply sloping. There are some steep areas with little vegetation.

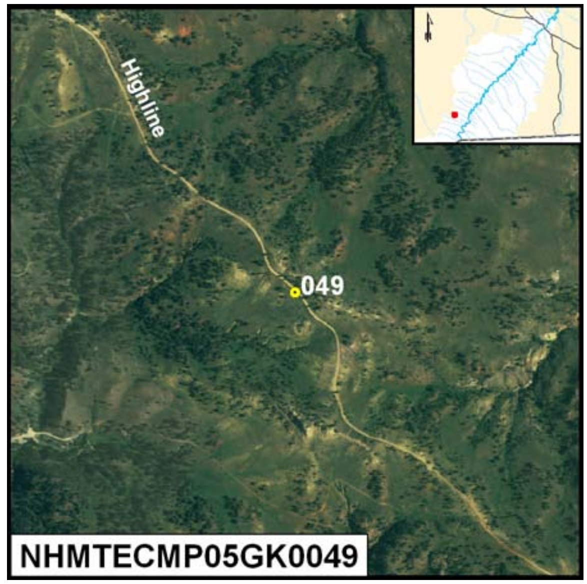


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0049
Photo Date: 8/28/2005

Photo Point Description

View of upper valley with dominant pine forests and patches of Wyoming sage. State land has been thinned. View is at 260 degrees.

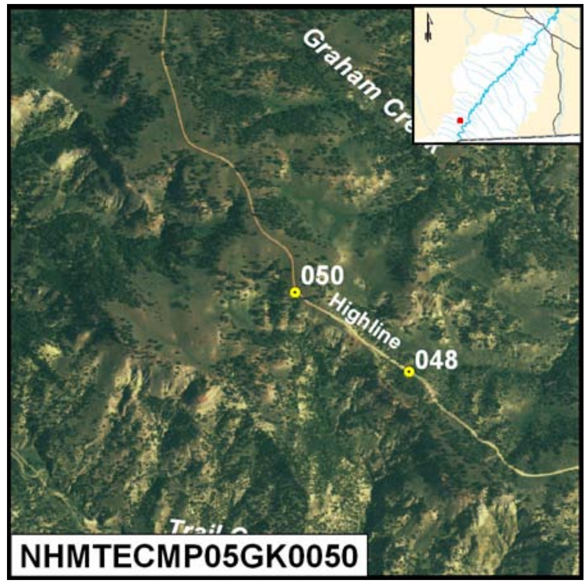


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0050
Photo Date: 8/28/2005

Photo Point Description

View at 165 degrees down Trail Creek drainage. Skunkbush sumac is common.

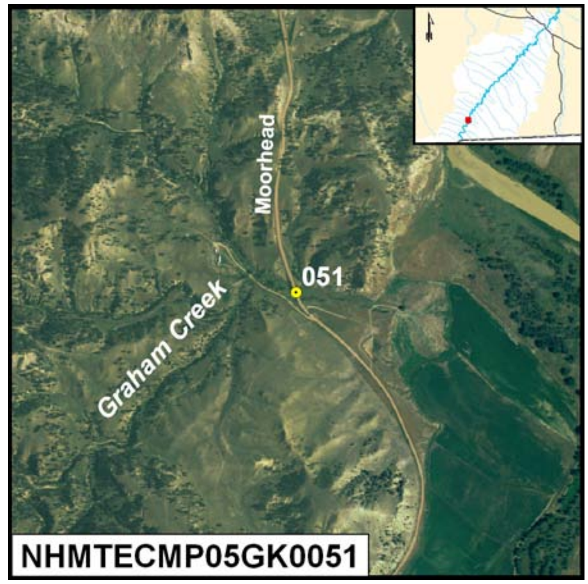


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0051
Photo Date: 8/28/2005

Photo Point Description

View up Graham Creek

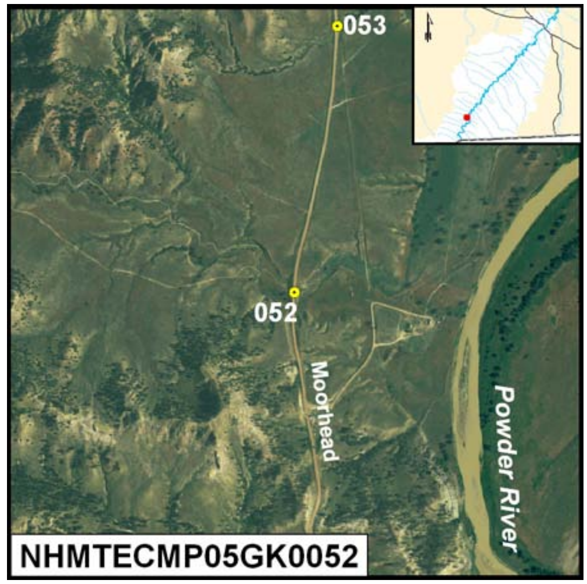


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0052
Photo Date: 8/28/2005

Photo Point Description

View up Thompson Creek. Some hardwoods up the creek. Looks like pine forest begins fairly soon up the valley.

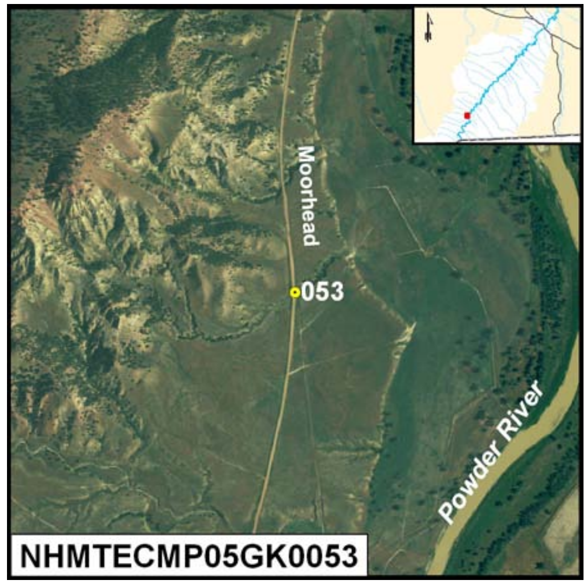


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0053
Photo Date: 8/28/2005

Photo Point Description

View up unnamed creek, deeply incised east of road with conifers and hardwood mixed, good woody vegetation structure. Upstream has some hardwoods.

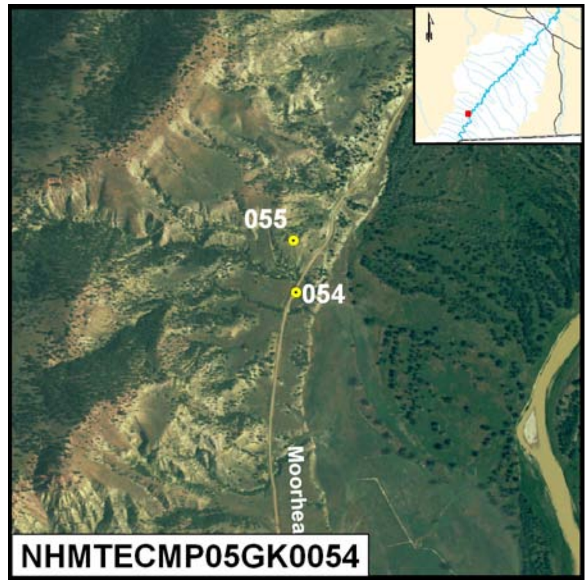


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0054
Photo Date: 8/28/2005

Photo Point Description

View of typical steep slopes along this part of the valley. These small incised tributaries often have good woody structure. Wyoming sage is the most common vegetation on these steep slopes.

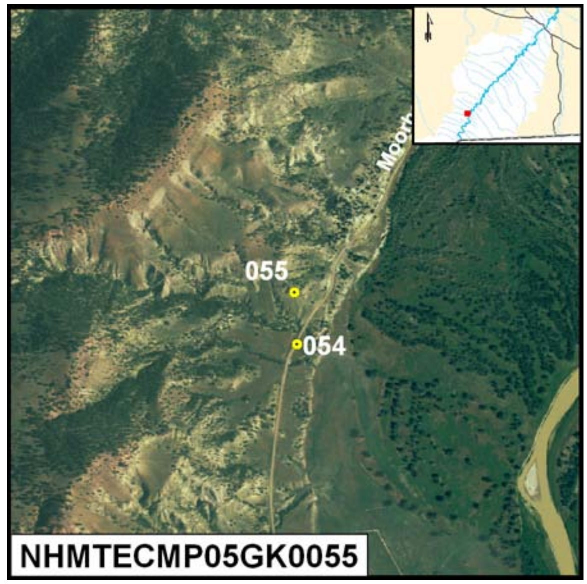


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0055
Photo Date: 8/28/2005

Photo Point Description

Closeup of steep slope, typically dominated by Wyoming sage, saltbush, and greasewood. Lower slopes have bluebunch transitioning to threadleaf sedge, little bluestem, needle and thread, soapweed yucca, and Japanese brome.

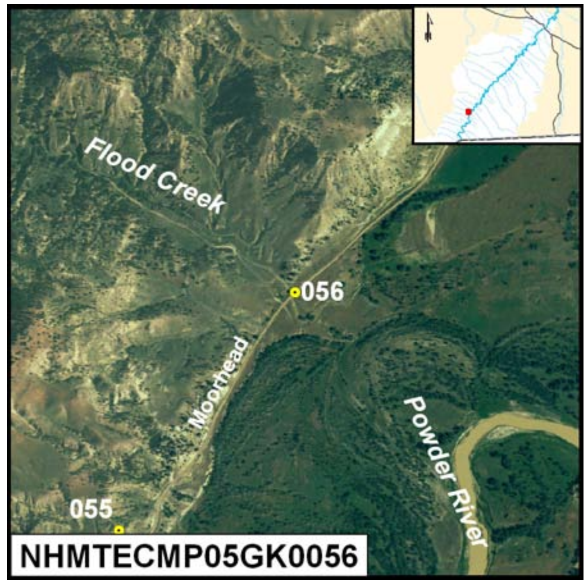


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0056
Photo Date: 8/28/2005

Photo Point Description

View up Flood Creek. Steep sided valley with little flat land. A few shrubs along creek but not much, no water.

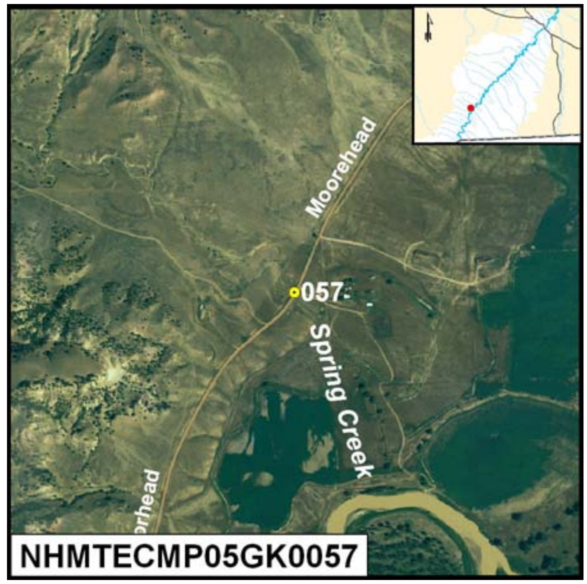


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0057
Photo Date: 8/28/2005

Photo Point Description

Spring Creek, somewhat broader valley here but steep sided slopes narrow in quickly.

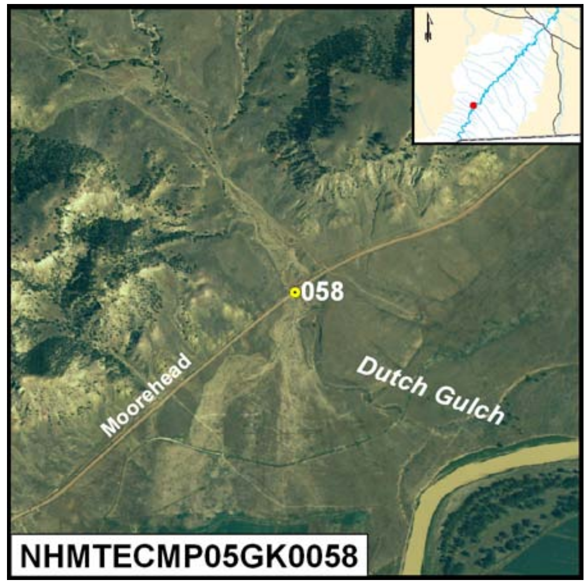


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0058
Photo Date: 8/28/2005

Photo Point Description

Dutch Gulch, similar to Spring Creek Valley. Sage is common. Some woody vegetation up the creek, looks like mostly conifers.

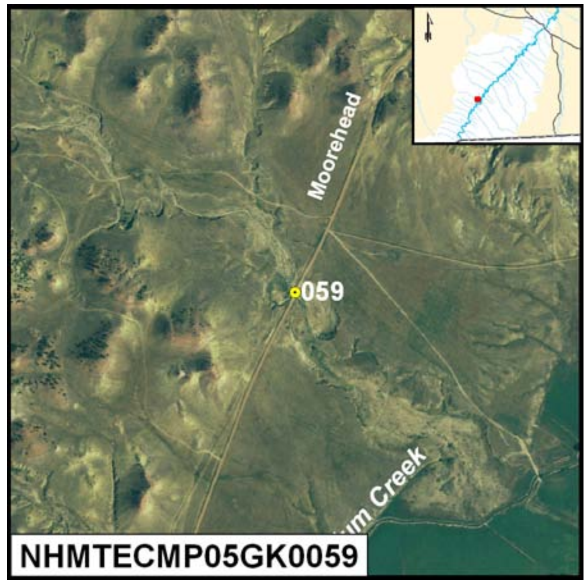


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0059
Photo Date: 8/28/2005

Photo Point Description

Plum Creek has little woody vegetation. Downstream of road there are very scattered cottonwoods and 10' incised banks. Upstream channel is somewhat incised. Rounded bare knobs here are typical of the last few miles to the south. Valleys north of here are shallow and more like extensions of the main Powder River Valley. Most tributaries have little woody vegetation. Surrounding hills are very steep. State land along road has blue grama, W. wheatgrass, and Japanese brome. There is little sage.

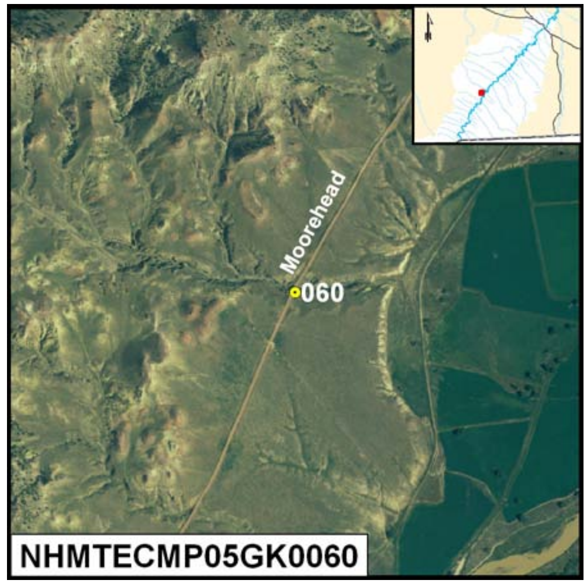


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0060
Photo Date: 8/28/2005

Photo Point Description

Steep incised tributary with dead cottonwood. 30' gully sides downstream of road.

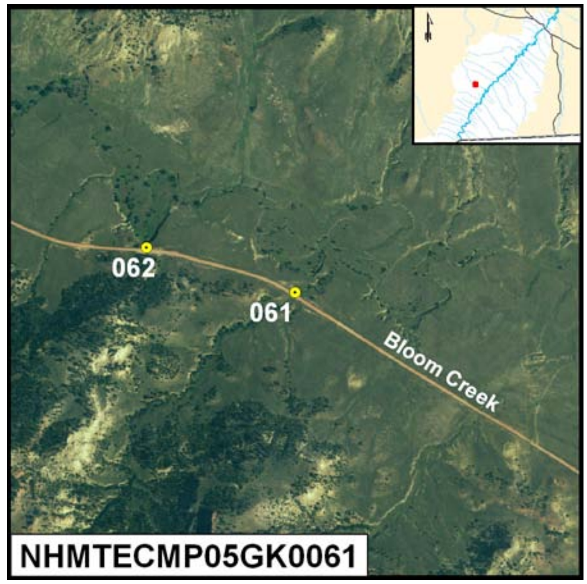


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0061
Photo Date: 8/28/2005

Photo Point Description

Bloom Creek valley is broader than southern valleys on this side of the Powder River and looks more like some subwatershed valleys east of the Powder River with considerably more trees on the south side compared to the somewhat steeper and barer north side (south facing). Cottonwoods are common along creek but widely scattered. Grassland vegetation has more needle and thread mixed in, sage is dense in some areas. View is NE down tributary and shows juniper, there is also cottonwood and box elder.

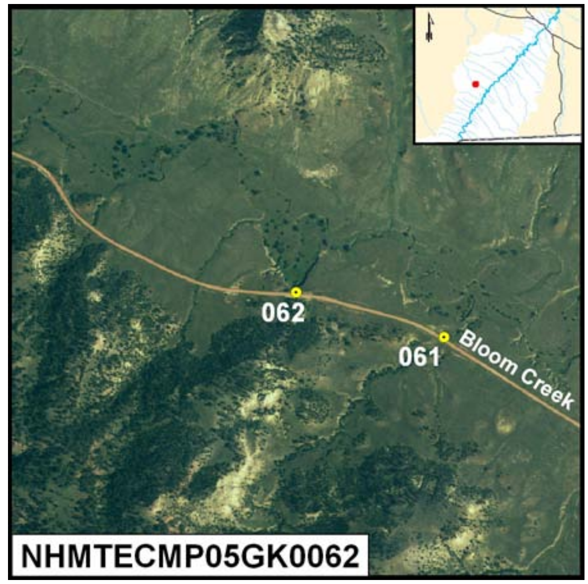


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0062
Photo Date: 8/28/2005

Photo Point Description

Variety of woody vegetation along Bloom Creek.

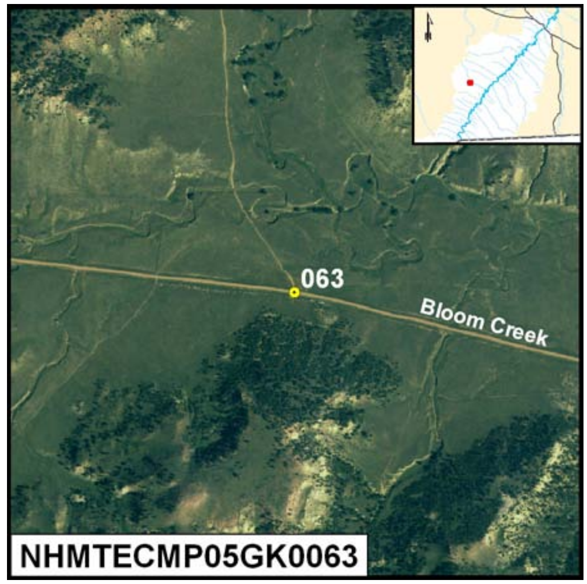


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0063
Photo Date: 8/28/2005

Photo Point Description

View of north fork of Bloom Creek with cottonwoods. This valley has fairly good woody cover of cottonwood, green ash, and snowberry. Silver sage is very common throughout. Valley bottom is sage/grass with fairly dense trees along valley sides as soon as they rise. Green ash seems the most common hardwood further upstream, cottonwoods are not very common. Secondary shrubs are not very common but sometimes present.

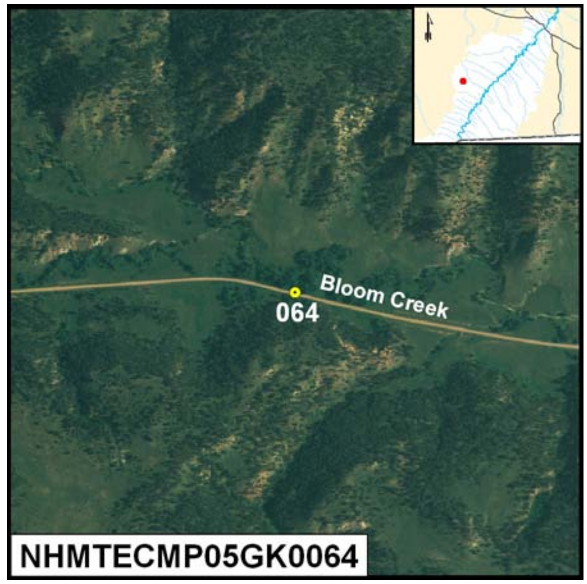


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0064
Photo Date: 8/28/2005

Photo Point Description

Multilayered canopy along south fork of Black Creek.

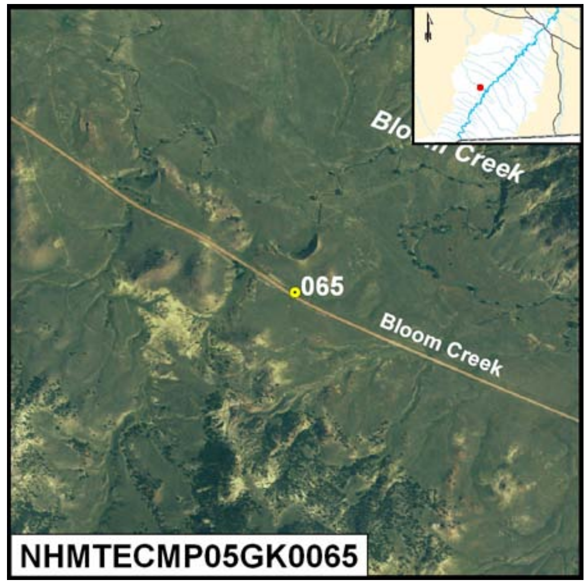


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0065
Photo Date: 8/28/2005

Photo Point Description

Lower Bloom Creek valley.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0066
Photo Date: 8/28/2005

Photo Point Description

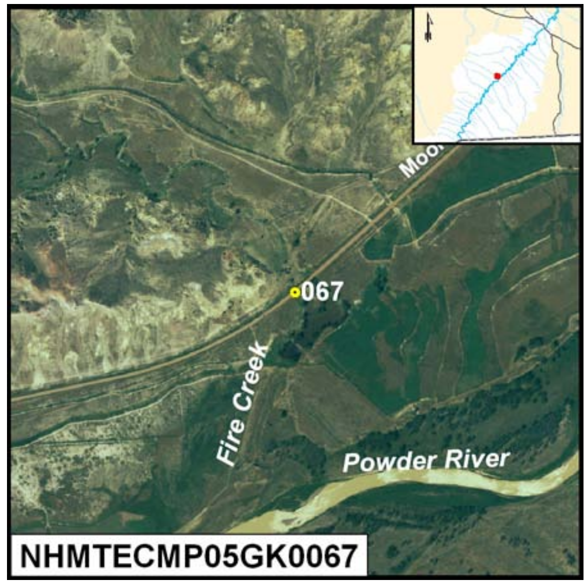
East Pinto Creek has virtually no woody vegetation. There are scattered sage and saltbush shrubs. Hills are quite bare and steep with very few trees. Extensive fields of crested wheat in these broad bottomlands.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0067
Photo Date: 8/28/2005

Photo Point Description

Fire Gulch has a few decadent cottonwoods west of road and a stock pond to the east ringed by cottonwoods. Valley has lower rounded hills with some sandstone outcrops. Sage is common, few trees.

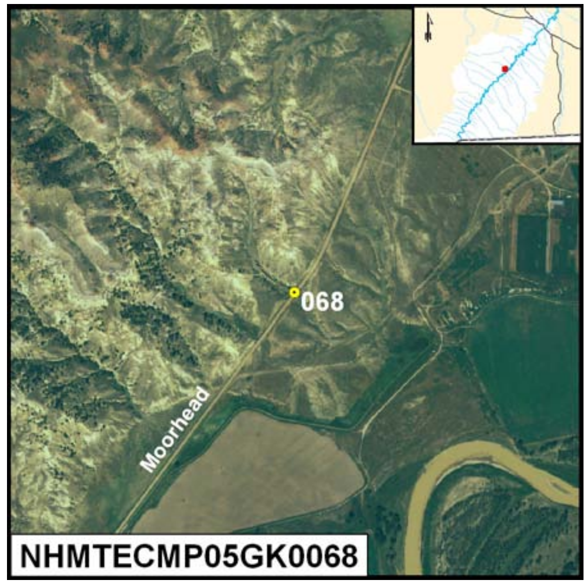


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0068
Photo Date: 8/28/2005

Photo Point Description

Small steep gulch.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0069
Photo Date: 8/28/2005

Photo Point Description

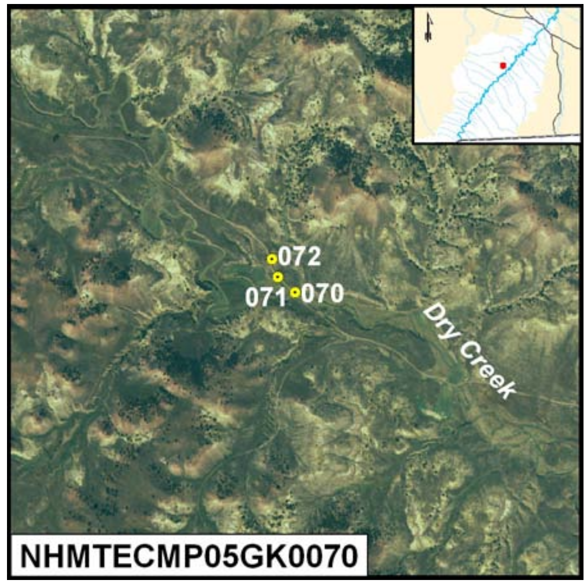
Dry Creek, no woody vegetation. Sage is common, especially on the toe slopes and this broad non-incised floodplain. Steep slopes have few trees. Crested wheat is extensive throughout this valley bottom.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0070
Photo Date: 8/28/2005

Photo Point Description

View up Dry Creek. Silver sage is common on the more mesic sites, Wyoming sage is more extensive above. Low rounded hills with steep sides. Spurge occurs here. Some trees in patches with favorable aspects.

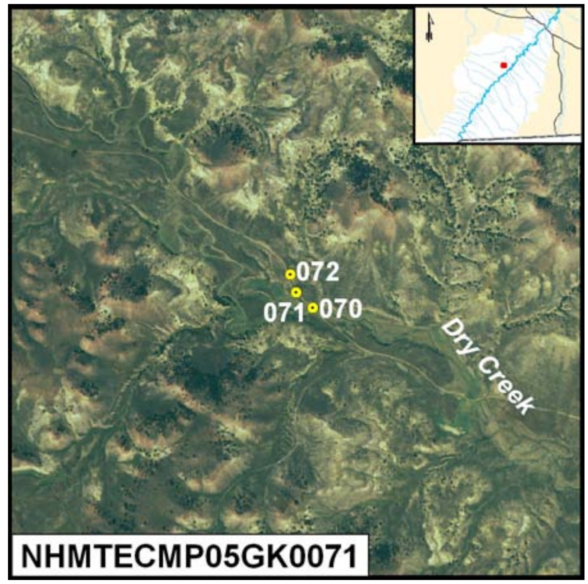


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0071
Photo Date: 8/28/2005

Photo Point Description

View south across Dry Creek.

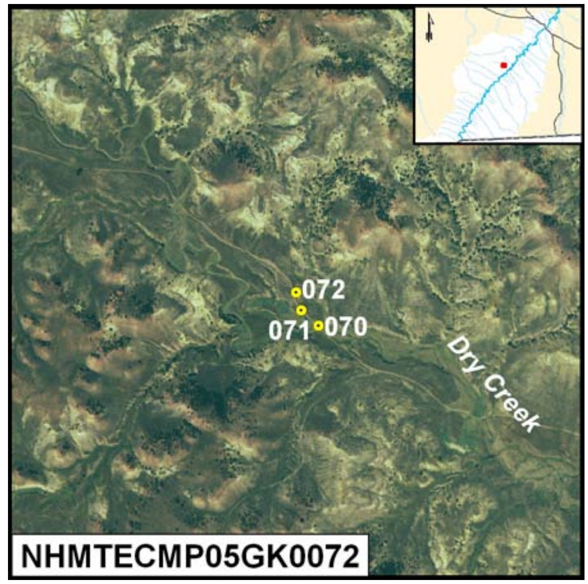


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0072
Photo Date: 8/28/2005

Photo Point Description

View up valley. Mix of crested wheat with western wheatgrass, bluebunch, needle and thread, and blue grama.

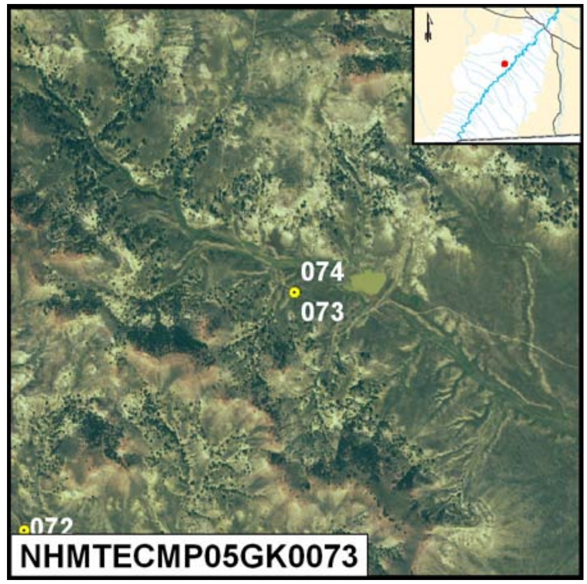


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0073
Photo Date: 8/28/2005

Photo Point Description

Flood Creek reservior. No woody vegetation except conifers in upper gullies. Silver and Wyoming sage are common throughout.

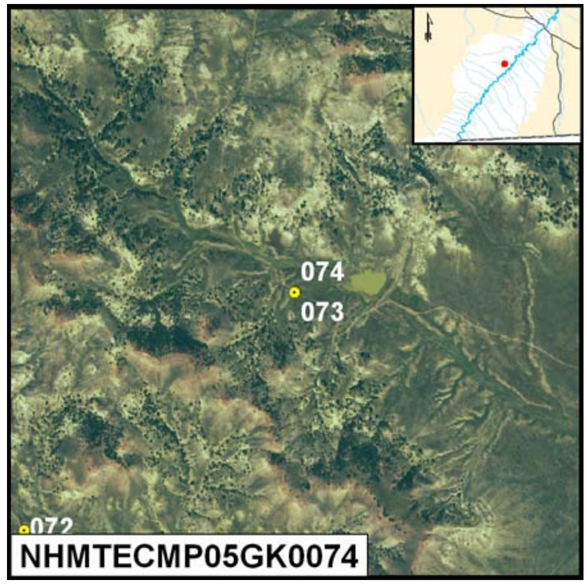


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0074
Photo Date: 8/28/2005

Photo Point Description

View north from same GPS point as previous photo. Common grasses include bluebunch, W. wheatgrass, blue grama, needle and thread. South end of this valley has extensive crested wheat.

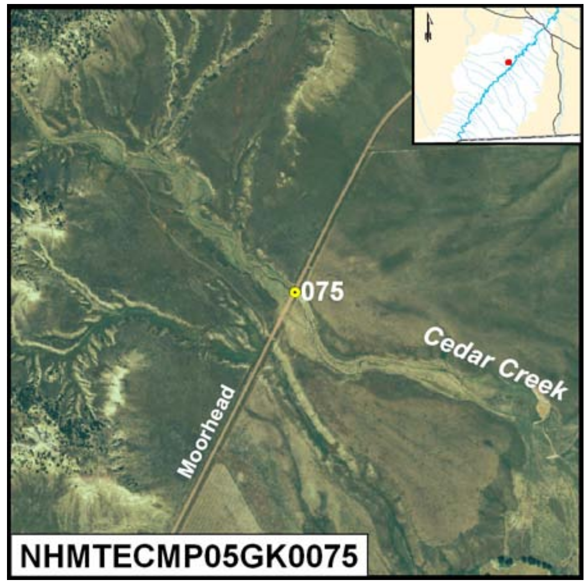


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0075
Photo Date: 8/28/2005

Photo Point Description

View up Cedar Creek. No woody vegetation other than sage, creek is somewhat incised. Valley closes in quickly and tree cover becomes heavy. Low but steep hills line the valley at this lower end. Fair amount of tree cover on hills.

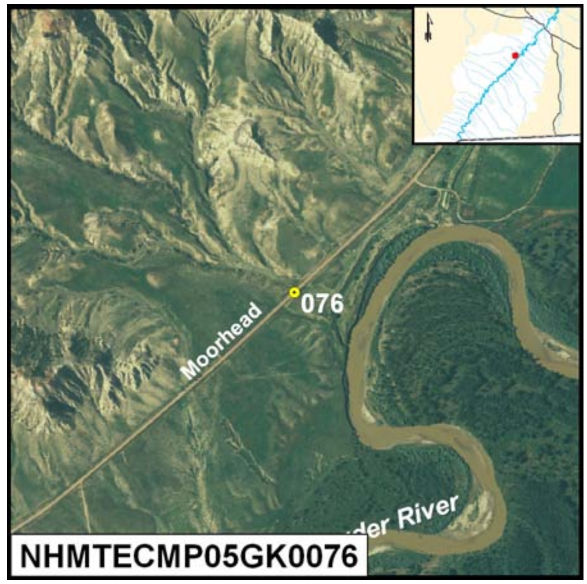


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0076
Photo Date: 8/29/2005

Photo Point Description

View up unnamed tributary of the Powder River. Valley here is narrow with steep cliffs and little tree cover. Regular sage cover. No woody vegetation along creek.

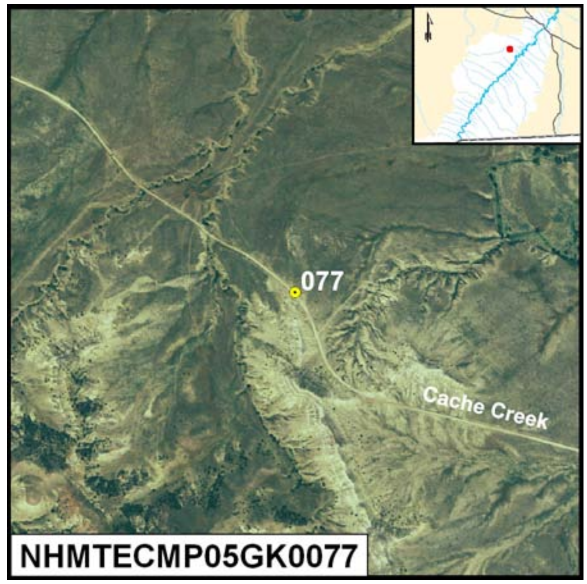


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0077
Photo Date: 8/29/2005

Photo Point Description

View down floodplain of Rock Spring Creek. Cottonwood forests are quite extensive and broaden downstream. Above this point the riparian forest starts to become non-continuous with scattered cottonwood trees and patches, about 50% of the riparian is occupied. The valley is quite broad with moderate tree cover on hills. Higher parts of hills are steep but there are extensive toeslopes. Sage is common and dense in some areas.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0078
Photo Date: 8/29/2005

Photo Point Description

View down Rock Spring Creek. Spurge is abundant. Stream is dry and incised about 12', no longer reaches historic floodplain. Silver sage is abundant on floodplain but not very common on valley flats which are a mix of blue grama, Japanese brome, W. wheatgrass, and needle and thread. Prickly pear and fringed sage are relatively abundant. There is no secondary shrub development along the river. Box elder is the most common tree after cottonwoods but green ash is also present. Channel is an unvegetated rut 2' deep.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0079
Photo Date: 8/29/2005

Photo Point Description

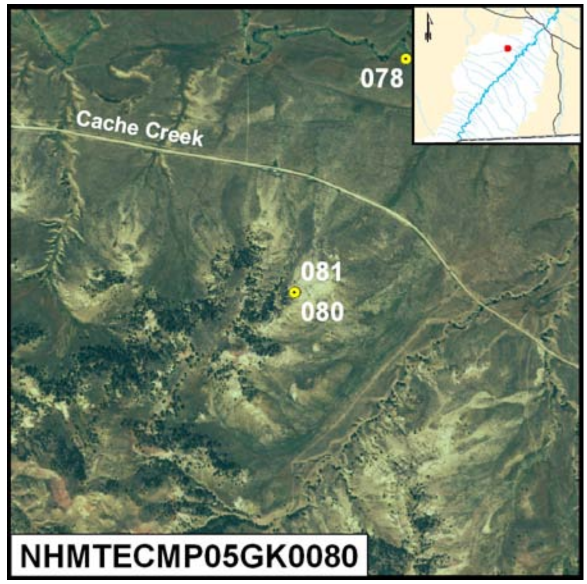
North view across valley from same gps point as previous photo view.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0080
Photo Date: 8/29/2005

Photo Point Description

Wyoming sage and saltbush with scattered bluebunch dominate vegetation on this eroded slope. Juniper and pine are common where conditions allow tree growth. There are some sandstone outcrops with the typical vegetation including soapweed yucca. Thread leaf sedge is common in eroded areas. Wyoming sage occurs also.

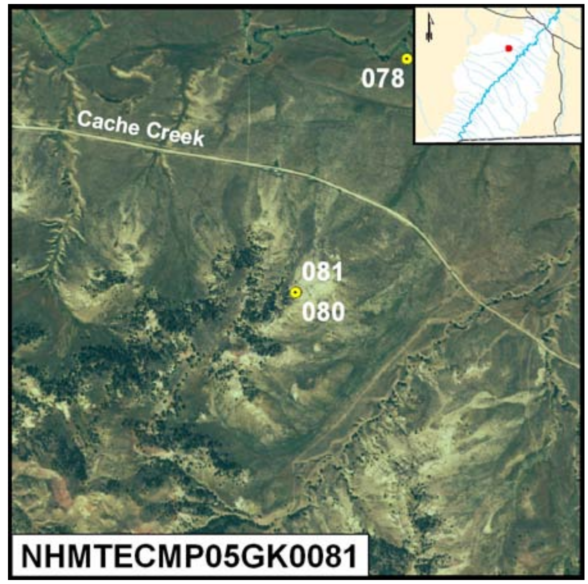


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0081
Photo Date: 8/29/2005

Photo Point Description

View across valley from same GPS point as previous photo plot.

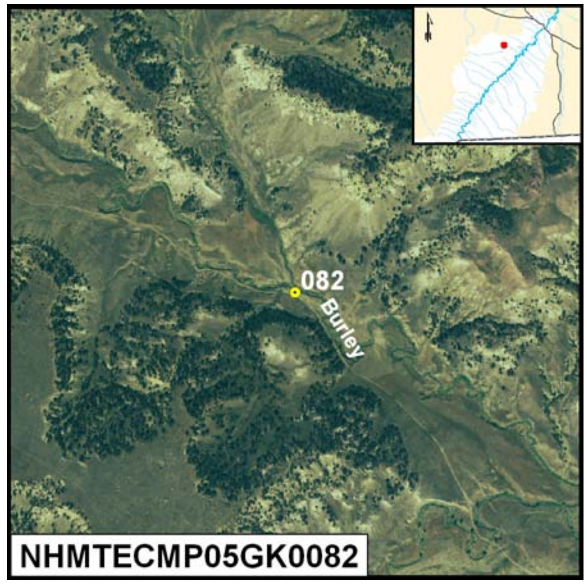


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0082
Photo Date: 8/29/2005

Photo Point Description

View up second of small tributaries at the end of Rock Creek valley. Location is approximate. Both are through steep canyons, this one has more trees. Bottom of Rock Creek valley has quite a wide cottonwood swath and large areas of hay production. Hills here are quite steep and eroded.

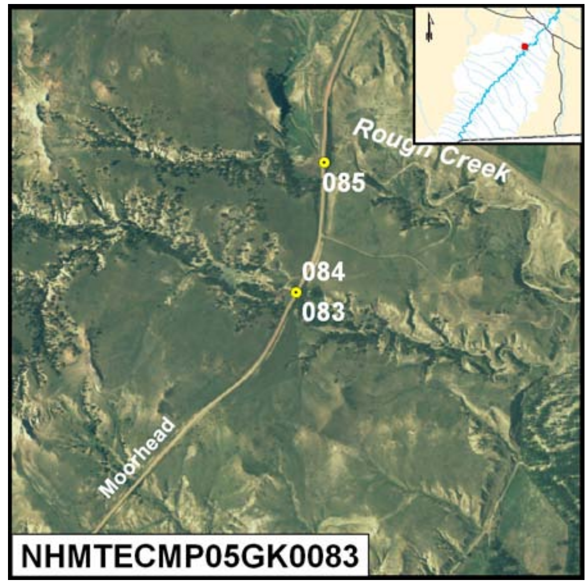


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0083
Photo Date: 8/29/2005

Photo Point Description

View up valley. This is a broad flat-bottomed canyon that is quite unique in this Middle Powder 4th code watershed. There is a mix of cottonwoods, junipers and other deciduous trees.

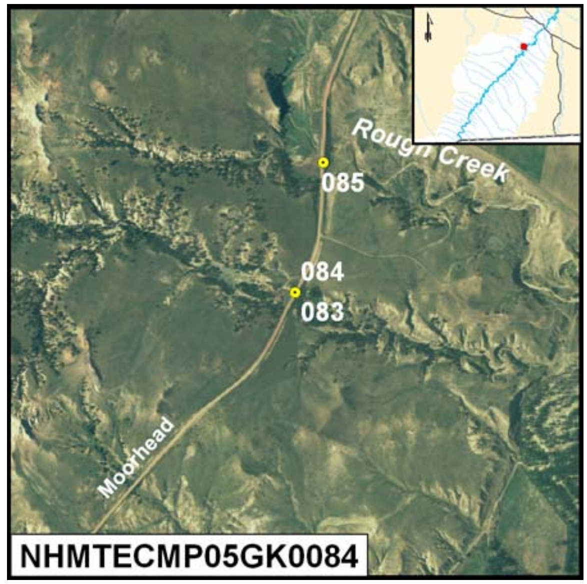


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0084
Photo Date: 8/29/2005

Photo Point Description

View down valley. This is a broad flat-bottomed canyon that is quite unique in this Middle Powder 4th code watershed. These is a mix of cottonwoods, junipers and other deciduous trees.

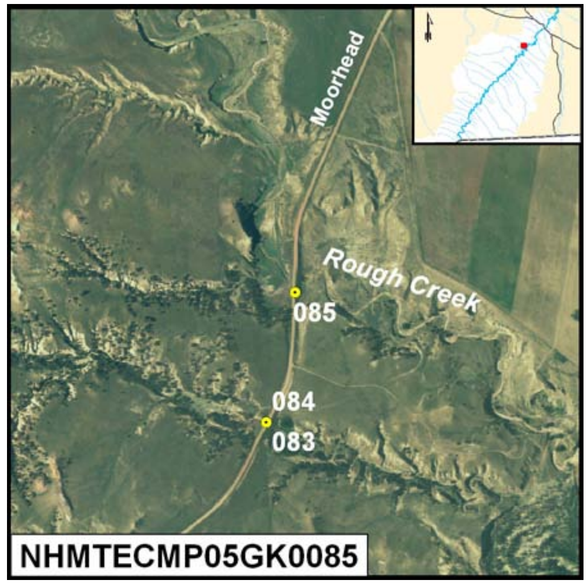


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0085
Photo Date: 8/29/2005

Photo Point Description

Rough Creek has a broad floodplain. Conifers are common, mostly juniper but some pines along steep slopes. A few cottonwoods are visible downstream. Sage is fairly common. Steep bare slopes are fairly typical for this part of the watershed. The flat valley botton here is largely used for hay cutting.

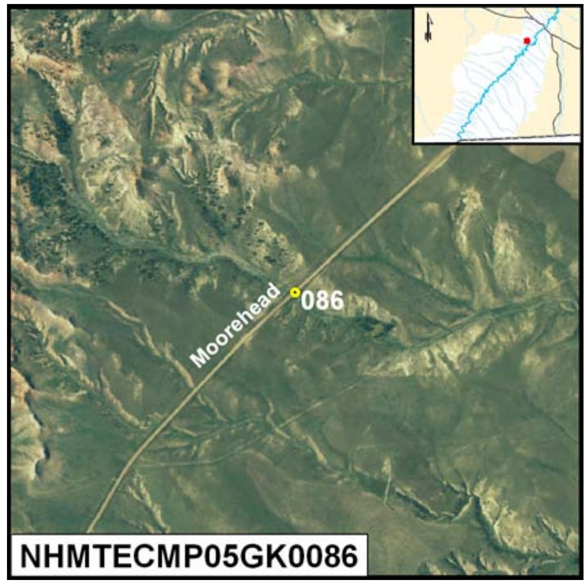


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0086
Photo Date: 8/29/2005

Photo Point Description

Cottonwood patch associated with unnamed tributary to the Powder River, wetland vegetation too. May be on BLM land. Upstream edges of gently sloping stream drainage has mix of pine and juniper.

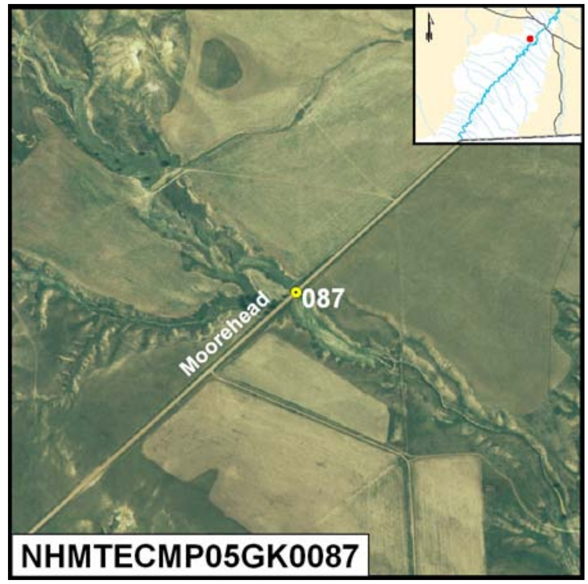


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0087
Photo Date: 8/29/2005

Photo Point Description

View up unnamed tributary in Wrangler Creek valley. Sunflower fields in lower valley near here along with crested wheat.

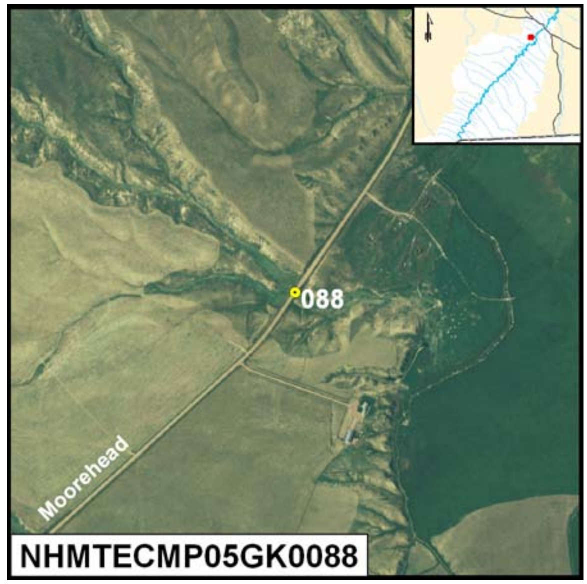


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0088
Photo Date: 8/29/2005

Photo Point Description

Wrangler Creek. Hay fields are common. Rolling, relatively flat grassland up to steep slopes at back of watershed, possibly more crested wheat with little sage.

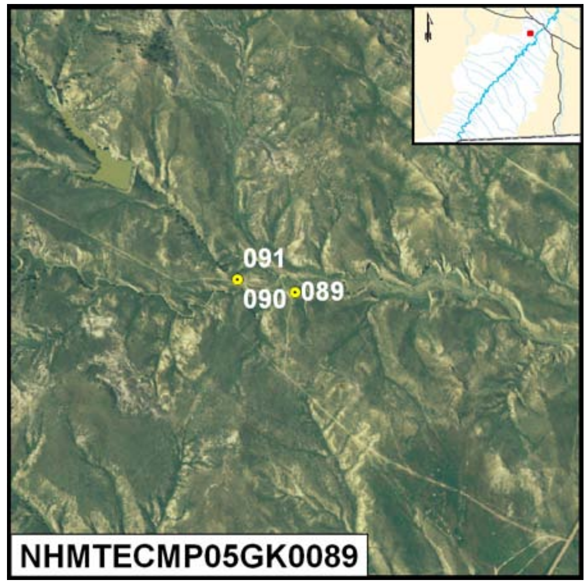


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0089
Photo Date: 8/29/2005

Photo Point Description

View of unnamed tributary in Wrangler Creek drainage. Scattered woody vegetation here, mostly juniper. Uplands have common sage, often dense with mix of blue grama, Japanese brome, and threadleaf sedge with some needle and thread and W. wheatgrass.



Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0090
Photo Date: 8/29/2005

Photo Point Description

Incised channel with common juniper.

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0091
Photo Date: 8/29/2005

Photo Point Description

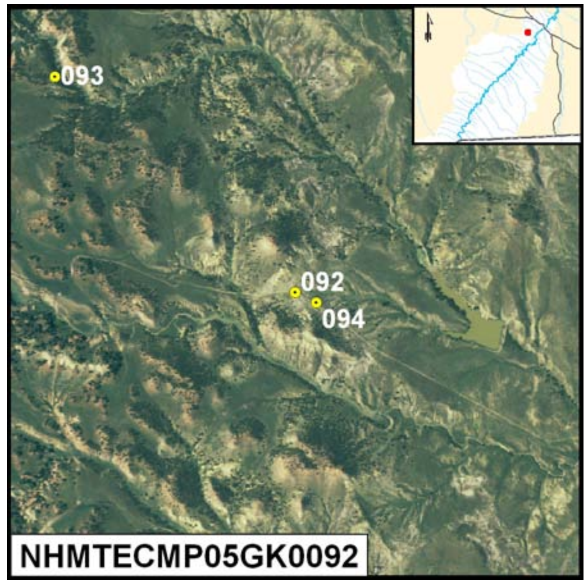
Incised channel with common juniper. Same gps photo point as previous plot

Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0092
Photo Date: 8/29/2005

Photo Point Description

View of upper valley. Juniper is common, pine is scattered. Sage is fairly heavy. There is a mix of grass species including bluebunch, needle and thread, W. wheatgrass, blue grama, little bluestem, etc. - a bit of everything.

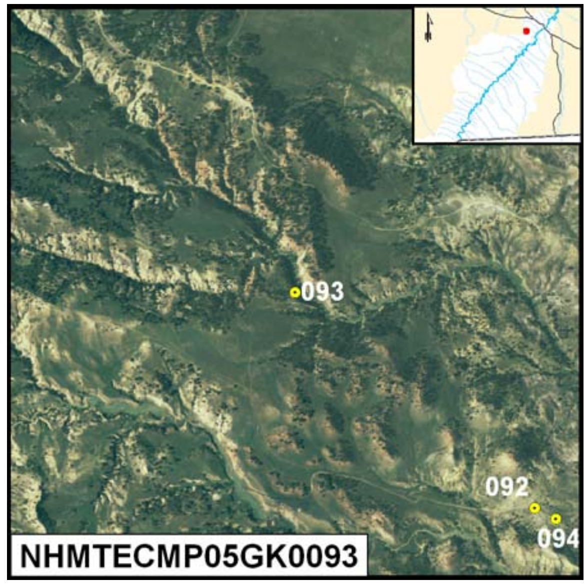


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0093
Photo Date: 8/29/2005

Photo Point Description

Upper valley view.

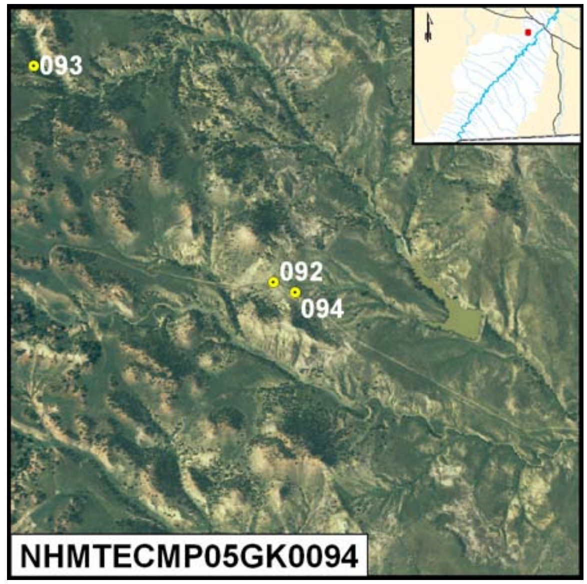


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0094
Photo Date: 8/29/2005

Photo Point Description

Stock reservior.

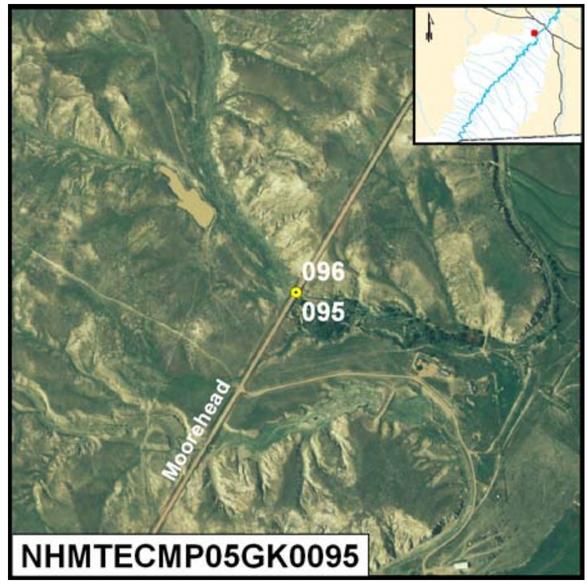


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0095
Photo Date: 8/29/2005

Photo Point Description

View upstream from road of small unnamed intermittent stream valley. Heavy sage cover on flats.

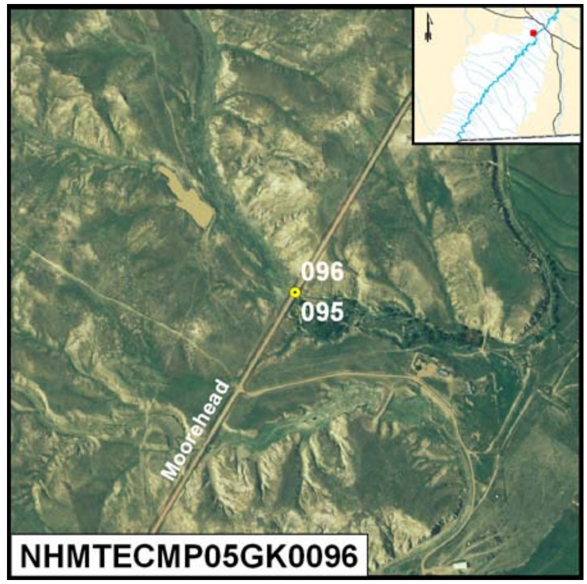


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0096
Photo Date: 8/29/2005

Photo Point Description

View downstream from road of small unnamed intermittent stream valley. Valley deepens here and holds nice stand of hardwood trees.

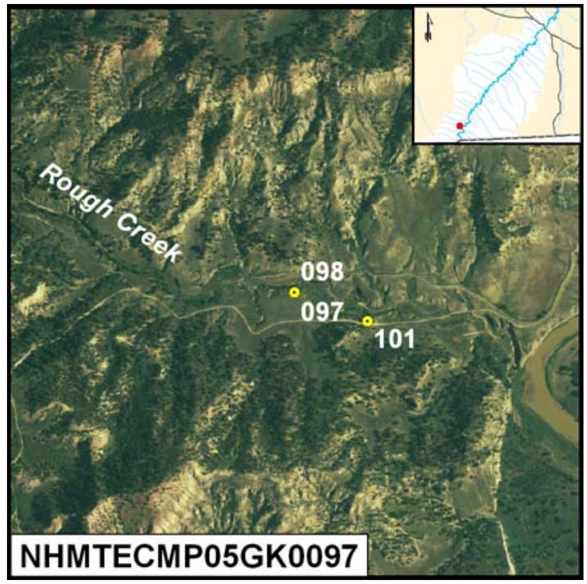


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0097
Photo Date: 8/29/2005

Photo Point Description

View of Rough Creek looking downstream. Stream channel is incised into gully.

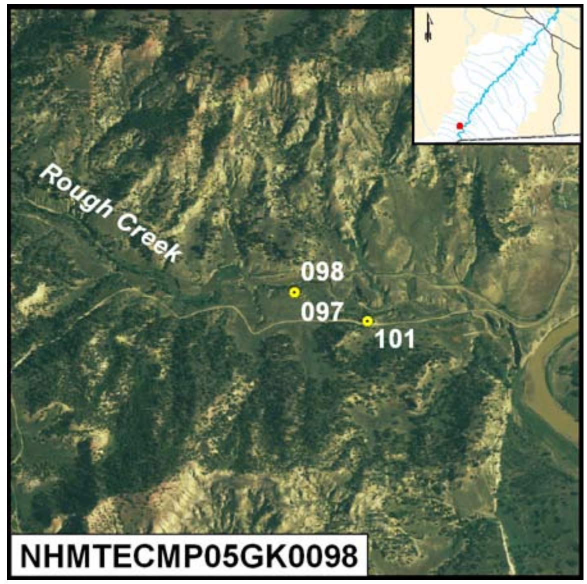


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0098
Photo Date: 8/29/2005

Photo Point Description

Upstream view of Rough Creek drainage from the same GPS point as previous plot. Sandstone outcrops are common in this rugged valley.

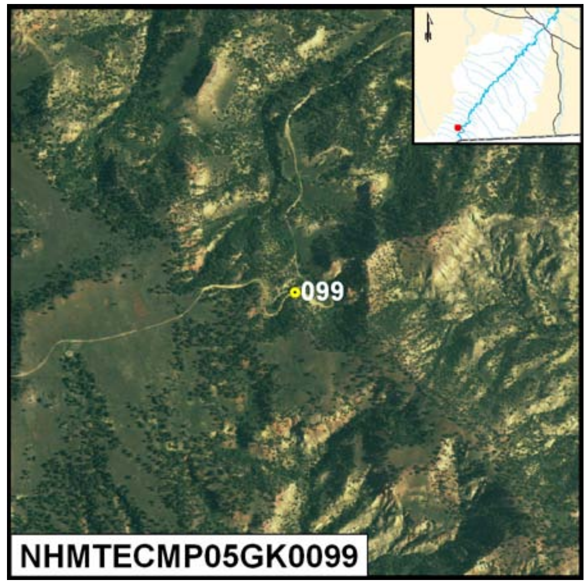


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0099
Photo Date: 8/29/2005

Photo Point Description

View up unnamed tributary of Rough Creek to watershed divide.

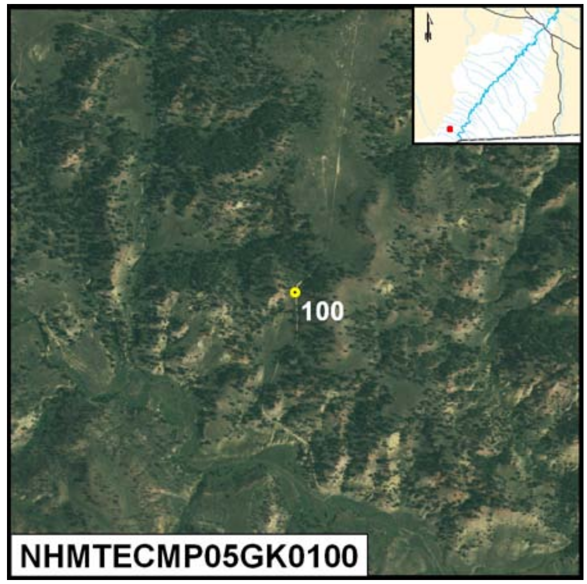


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0100
Photo Date: 8/29/2005

Photo Point Description

View into Bradshaw Creek Valley from the northern divide. Far hillside had a wildfire a few years ago that killed most of the trees.

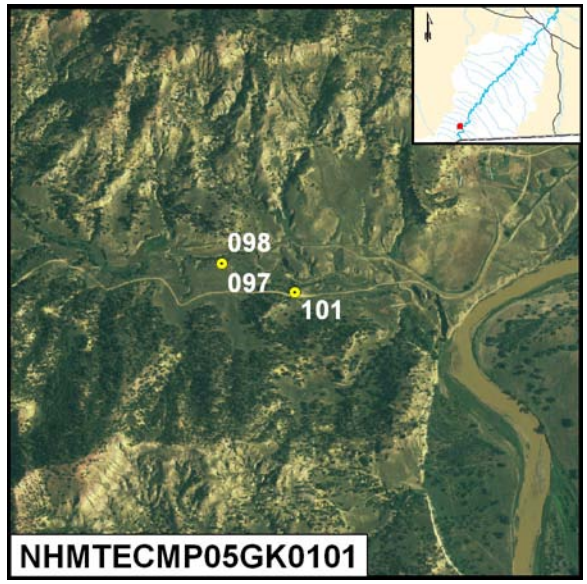


Middle Powder Watershed Assessment Photo Point

Site ID: NHMTECMP05GK0101
Photo Date: 8/29/2005

Photo Point Description

Sandstone bluff in lower Rough Creek Valley.



Appendix C. Frequencies of Fish Species Occurrence Across Different Segments of the Powder River

All sites includes 2 Wyoming sites @ river mile 225 and 235, all MT sites includes sites from river mile (rm) 220 downstream to the confluence with the Yellowstone. F of O is frequency of fish species occurring. Bolded are > .5

	F of O	F of O	F of O	F of O	F of O
	All Sites (n=30)	All MT Sites (n=28)	Lower 20rm (n=10)	All Sites >20rm (n=18)	1975 BR sites (n=7)
Brassy Minnow[1]	0.03	0.04	0.00	0.06	0.14
Burbot	0.10	0.11	0.13	0.06	0.29
Channel Catfish	**0.93**	**0.96**	**1.00**	**0.94**	**1.00**
Common Carp[1]	0.20	0.21	0.38	0.17	0.29
Creek Chub	0.07	0.07	0.00	0.06	0.14
Flathead Chub	**0.97**	**0.96**	**0.88**	**1.00**	**1.00**
Goldeye	**0.60**	**0.61**	**1.00**	0.44	**0.57**
Green Sunfish[1]	0.07	0.07	0.00	0.11	0.29
Lake Chub	0.13	0.14	0.00	0.22	**0.57**
Longnose Dace	0.50	0.46	0.00	**0.83**	**0.71**
Longnose Sucker	0.07	0.07	0.25	0.00	0.00
Plains Minnow	**0.47**	**0.50**	0.00	**0.67**	0.43
Plains Killifish[1]	0.17	0.14	0.00	0.28	0.00
River Carpsucker	**0.57**	**0.57**	0.38	**0.61**	**0.57**
Sand Shiner	0.50	0.46	0.00	**0.67**	0.14
Sauger	0.33	0.36	**1.00**	0.06	0.29
Shorthead Redhorse	0.40	0.43	**0.88**	0.32	0.29
Shovelnose Sturgeon	0.20	0.21	**0.75**	0.00	0.00
Stonecat	0.13	0.11	0.13	0.22	0.14
Sturgeon Chub	**0.50**	**0.54**	0.13	**0.61**	**1.00**
Walleye	0.17	0.18	**0.63**	0.00	0.00
Western Silvery Minnow	**0.60**	**0.57**	**0.50**	**0.67**	**0.71**
Total # Expected Species	**7.70**	**7.79**	**8.00**	**7.53**	**8.57**
Total # species >50%	**7.00**	**7.00**	**8.00**	**8.00**	**8.00**

[1]Species not included in the sum for total expected species.

Appendix D. Macroinvertebrate Taxa Lists, Abundance and Plains MMI Calculations at Each Site

Powder River, Site 1 @ Wyoming border. Targeted-Riffle EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Order	FinalID	Individuals	TolVal[1]	FFG[2]	Habit[3]
Coleoptera	*Helichus*	2	5	SC	"CN/75%, CM/25%"
Coleoptera	*Microcylloepus pusillus*	7	5	CG	"CN/50%, BU/50%"
Coleoptera	*Stenelmis*	6	5	SC/CG	"CN/50%, BU/50%"
Diptera	*Polypedilum*	7	6	SH	CN
Diptera	*Hemerodromia*	5	6	PR	SP
Diptera	*Cricotopus*	1	8	CG/SH	CN
Diptera	*Simulium*	78	5	CF	CN
Ephemeroptera	*Traverella albertana*	234	2	CF	CN
Ephemeroptera	*Raptoheptagenia cruentata*	8	2	PR	CN
Ephemeroptera	*Acentrella turbida*	1	4	CG	"SW/10%, CN/90%"
Ephemeroptera	*Acerpenna*	2	4	SC	"SW/10%, CN/90%"
Ephemeroptera	*Cercobrachys*	3	6	CG	"SP/75%, CM/90%"
Ephemeroptera	*Fallceon quilleri*	22	5	CG	"SW/10%, CN/90%"
Ephemeroptera	*Hexagenia limbata*	5	6	CG	BU
Ephemeroptera	*Isonychia*	15	2	CF	SW/CN
Ephemeroptera	*Leucrocuta*	8	1	SC	CN
Ephemeroptera	*Tricorythodes*	44	4	CG	CN/SP
Haplotaxida	*Tubificidae*	2	10	CG	BU
Hemiptera	*Ambrysus mormon*	5	3	PR	unk
Odonata	*Ophiogomphus severus*	2	5	PR	unk
Odonata	*Stylurus intricatus*	1		PR	unk
Plecoptera	*Acroneuria abnormis*	2	2	PR	CN
Trichoptera	*Hydropsyche confusa*	4		unk	CN
Trichoptera	*Brachycentrus occidentalis*	6	2	CF	CN
Trichoptera	*Cheumatopsyche*	124	5	CF	CN
Trichoptera	*Hydropsyche morosa gr.*	3	6	unk	CN

[1] Tolval are general tolerance designations to nutrient pollution, water temperature, sediment deposition and other stressor. 0=very sensitive, 5=moderately tolerant, 10=extremely tolerant
[2] FFG designations MT DEQ has assigned. CG = collector-gatherer; CF = collector-filterer; SC= scraper; SH=shredder; PR=predator; OM=omnivore; UN=unknown.
[3]Habit is the general activity of the invertebrate. BU=Burrower, CM=Climber, SP=Sprawler, CN=Clinger, SW=Swimmer

Powder River Site 1 @ Wyoming border. Reach-wide EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Order	FinalID	Individuals	TolVal[1]	FFG[2]	Habit[3]
Coleoptera	*Dubiraphia*	1	6	SC/CG	"CN/50%, BU/50%"
Coleoptera	*Microcylloepus pusillus*	10	5	CG	"CN/50%, BU/50%"
Coleoptera	*Stenelmis*	4	5	SC/CG	"CN/50%, BU/50%"
Diptera	*Potthastia gaedii Gr.*	1	3	CG	SP
Diptera	*Polypedilum*	18	6	SH	CN
Diptera	*Hemerodromia*	6	6	PR	SP
Diptera	*Simulium*	5	5	CF	CN
Ephemeroptera	*Raptoheptagenia cruentata*	13	2	PR	CN
Ephemeroptera	*Traverella albertana*	19	2	CF	CN
Ephemeroptera	*Acentrella insignificans*	1	4	CG	"SW/10%, CN/90%"
Ephemeroptera	*Acerpenna*	2	4	SC	"SW/10%, CN/90%"
Ephemeroptera	*Caenis latipennis*	1	7	CG	"SP/75%, CM/90%"
Ephemeroptera	*Cercobrachys*	6	6	CG	"SP/75%, CM/90%"
Ephemeroptera	*Fallceon quilleri*	3	5	CG	"SW/10%, CN/90%"
Ephemeroptera	*Heptagenia*	6	4	SC	CN
Ephemeroptera	*Hexagenia limbata*	3	6	CG	BU
Ephemeroptera	*Leucrocuta*	4	1	SC	CN
Ephemeroptera	*Tricorythodes*	38	4	CG	CN/SP
Haplotaxida	*Lumbricina*	1	4	CG	BU
Hemiptera	*Corixidae*	1	9	PH/PR	SW
Hemiptera	*Ambrysus mormon*	4	3	PR	unk
Non-Insect taxa	*Nematoda*	2	5	unk	BU
Plecoptera	*Acroneuria abnormis*	1	2	PR	CN
Trichoptera	*Cheumatopsyche*	130	5	CF	CN
Trichoptera	*Hydropsyche morosa gr.*	7	6	unk	CN
Trichoptera	*Ithytrichia*	1	4	SC	unk
Trichoptera	*Nectopsyche*	7	2	SH	CM/SP/CN

[1] Tolval are general tolerance designations to nutrient pollution, water temperature, sediment deposition and other stressor. 0=very sensitive, 5=moderately tolerant, 10=extremely tolerant
[2] FFG designations MT DEQ has assigned. CG = collector-gatherer; CF = collector-filterer; SC= scraper; SH=shredder; PR=predator; OM=omnivore; UN=unknown.
[3]Habit is the general activity of the invertebrate. BU=Burrower, CM=Climber, SP=Sprawler, CN=Clinger, SW=Swimmer

Powder River Site 2 @ Dry Creek. Targeted-Riffle EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Montana Bioassessment Report

Waterbody Name:	Powder River@drycreek	**Benthic Sample ID:**	14902
Station ID:	YLBLMPW2T5	**Rep. Num:**	0
Reference		**STORET Activity ID:**	PW2T5-M
Site Classification:		**Collection Date:**	07/11/2005
Latitude:		**Collection**	EMAP_T500
Longitude:		**Total Number of Individuals in Sample:**	

Sample Taxa List

Order:	*OTU name:*	*FinalID:*	*Individuals*	*Tol Val:*	*FFG:*	*Habit:*
Coleoptera	Helichus	Helichus	1	5	SC	"CN/75%, CM/25%"
Coleoptera	Microcylloepus	Microcylloepus pusillus	3	5	CG	"CN/50%, BU/50%"
Coleoptera	Stenelmis	Stenelmis	2	5	SC/CG	"CN/50%, BU/50%"
Diptera	Chironominae	Polypedilum	5	6	SH	CN
Diptera	Hemerodromia	Hemerodromia	5	6	PR	SP
Diptera	Orthocladiinae	Orthocladius	1	7	CG	SP/BU
Diptera	Orthocladiinae	Parakiefferiella	1	6	CG	SP
Diptera	Simuliidae	Simulium	125	5	CF	CN
Ephemeropte		Raptoheptagenia cruentata	14	2	PR	CN
Ephemeropte		Traverella albertana	244	2	CF	CN
Ephemeropte	Acentrella	Acentrella turbida	1	4	CG	"SW/10%, CN/90%"
Ephemeropte	Cercobrachys	Cercobrachys	3		CG	"SP/75%, CM/90%"
Ephemeropte	Fallceon	Fallceon quilleri	12	5	CG	"SW/10%, CN/90%"
Ephemeropte	Hexagenia	Hexagenia limbata	12	6	CG	BU
Ephemeropte	Isonychia	Isonychia	8	2	CF	SW/CN
Ephemeropte	Leucrocuta	Leucrocuta	4	1	SC	CN
Ephemeropte	Tricorythodes	Tricorythodes	38	4	CG	CN/SP
Haplotaxida	Oligochaeta	Tubificidae	2	10	CG	BU
Hemiptera	Naucoridae	Ambrysus mormon	2	3	PR	unk
Odonata	Gomphidae	Ophiogomphus severus	3	5	PR	unk
Plecoptera	Acroneuria	Acroneuria abnormis	2	2	PR	CN
Trichoptera		Hydropsyche confusa	1	6	unk	CN
Trichoptera	Brachycentrus	Brachycentrus occidentalis	1	2	CF	CN
Trichoptera	Cheumatopsyche	Cheumatopsyche	105	5	CF	CN
Trichoptera	Hydropsyche_Cer	Hydropsyche morosa gr.	16	6	unk	CN
TRICHOPTE	Potamyia	POTAMYIA FLAVA	2	4	CF	

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[3]Habit is the general activity of the invertebrate. BU=Burrower, CM=Climber, SP=Sprawler, CN=Clinger, SW=Swimmer

Powder River Site 2 @ Dry Creek. Reach-Wide EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value.

Montana Bioassessment Report

Waterbody Name: Powder River@drycreek

Station ID: YLBLMPW205

Site Classification: **Collection Date:** 07/11/2005

Sample Taxa List

Order:	*OTU name:*	*FinalID:*	*Individuals*	*Tol Val:*	*FFG:*	*Habit:*
Coleoptera	Dubiraphia	Dubiraphia	1	6	SC/CG	"CN/50%, BU/50%"
Diptera	Chironominae	Cryptochironomus	3	8	PR	BU/SP
Diptera	Chironominae	Polypedilum	1	6	SH	CN
Diptera	Chironominae	Robackia	2	4	CG	unk
Diptera	Hemerodromia	Hemerodromia	3	6	PR	SP
Diptera	Orthocladiinae	Cricotopus bicinctus Gr.	2	9	CG/SH	CN
Diptera	Simuliidae	Simulium	21	5	CF	CN
Ephemeropte		Homoeoneuria alleni	2	2	CF	BU
Ephemeropte		Raptoheptagenia cruentata	9	2	PR	CN
Ephemeropte		Traverella albertana	35	2	CF	CN
Ephemeropte	Acentrella	Acentrella insignificans	1	4	CG	"SW/10%, CN/90%"
Ephemeropte	Anepeorus	Anepeorus rusticus	2	1	PR	CN
Ephemeropte	Cercobrachys	Cercobrachys	41		CG	"SP/75%, CM/90%"
Ephemeropte	Fallceon	Fallceon quilleri	9	5	CG	"SW/10%, CN/90%"
Ephemeropte	Heptagenia	Heptagenia	3	4	SC	CN
Ephemeropte	Hexagenia	Hexagenia limbata	4	6	CG	BU
Ephemeropte	Isonychia	Isonychia	1	2	CF	SW/CN
Ephemeropte	Leucrocuta	Leucrocuta	4	1	SC	CN
Ephemeropte	Tricorythodes	Tricorythodes	56	4	CG	CN/SP
Haplotaxida	Oligochaeta	Tubificidae	1	10	CG	BU
Odonata	Gomphidae	Ophiogomphus severus	2	5	PR	unk
Odonata	Gomphidae	Stylurus intricatus	4	2	PR	unk
Trichoptera	Cheumatopsyche	Cheumatopsyche	30	5	CF	CN
Trichoptera	Hydropsyche_Cer	Hydropsyche morosa gr.	16	6	unk	CN
Trichoptera	Nectopsyche	Nectopsyche	4	2	SH	CM/SP/CN

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[2] FFG designations MT DEQ has assigned. CG = collector-gatherer; CF = collector-filterer; SC= scraper; SH=shredder; PR=predator; OM=omnivore; UN=unknown.
[3]Habit is the general activity of the invertebrate. BU=Burrower, CM=Climber, SP=Sprawler, CN=Clinger, SW=Swimmer

Powder River Site 3 @ Jenkins Creek. Targeted-Riffle & Reach-Wide EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Waterbody Name: Powder River@Jenkins Targeted-Riffle

Station ID: YLBLMPW3T5

Order:	OTU name:	Taxa	Individuals	Tol Val:	FFG:	Habit:
Basommatop	Planorbidae	Gyraulus	2	8	CG	CN
Coleoptera	Microcylloepus	Microcylloepus pusillus	1	5	CG	"CN/50%, BU/50%"
Coleoptera	Stenelmis	Stenelmis	2	5	SC/CG	"CN/50%, BU/50%"
Diptera	Chironominae	Polypedilum	15	6	SH	CN
Diptera	Chironominae	Robackia	1	4	CG	unk
Diptera	Hemerodromia	Hemerodromia	1	6	PR	SP
Diptera	Simuliidae	Simulium	17	5	CF	CN
Ephemeropte		Raptoheptagenia cruentata	13	2	PR	CN
Ephemeropte		Traverella albertana	72	2	CF	CN
Ephemeropte	Acerpenna	Acerpenna	1	4	SC	"SW/10%, CN/90%"
Ephemeropte	Cercobrachys	Cercobrachys	4		CG	"SP/75%, CM/90%"
Ephemeropte	Choroterpes	Choroterpes	3	2	CG	CN/SP
Ephemeropte	Fallceon	Fallceon quilleri	1	5	CG	"SW/10%, CN/90%"
Ephemeropte	Heptagenia	Heptagenia	2	4	SC	CN
Ephemeropte	Hexagenia	Hexagenia limbata	1	6	CG	BU
Ephemeropte	Isonychia	Isonychia	4	2	CF	SW/CN
Ephemeropte	Leucrocuta	Leucrocuta	3	1	SC	CN
Ephemeropte	Pseudocloeon	Pseudocloeon	2	4	CG	"SW/10%, CN/90%"
Ephemeropte	Tricorythodes	Tricorythodes	21	4	CG	CN/SP
Haplotaxida	Oligochaeta	Tubificidae	1	10	CG	BU
Hemiptera	Naucoridae	Ambrysus mormon	1	3	PR	unk
Trichoptera	Cheumatopsyche	Cheumatopsyche	62	5	CF	CN
Trichoptera	Hydropsyche_Cer	Hydropsyche morosa gr.	1	6	unk	CN
Trichoptera	Nectopsyche	Nectopsyche	2	2	SH	CM/SP/CN
Trombidiform	Acarina	Sperchon	2	5	PR	unk

Waterbody Name: Powder River@Jenkins Reach-Wide

Station ID: YLBLMPW305

Order:	OTU name:	Taxa:	Individuals	Tol Val:	FFG:	Habit:
Basommatop	Planorbidae	Gyraulus	3	8	CG	CN
Coleoptera	Microcylloepus	Microcylloepus pusillus	3	5	CG	"CN/50%, BU/50%"
Coleoptera	Stenelmis	Stenelmis	2	5	SC/CG	"CN/50%, BU/50%"
Diptera	Chironominae	Polypedilum	7	6	SH	CN
Diptera	Simuliidae	Simulium	3	5	CF	CN
Ephemeropte		Raptoheptagenia cruentata	5	2	PR	CN
Ephemeropte		Traverella albertana	25	2	CF	CN
Ephemeropte	Acerpenna	Acerpenna	5	4	SC	"SW/10%, CN/90%"
Ephemeropte	Cercobrachys	Cercobrachys	6		CG	"SP/75%, CM/90%"
Ephemeropte	Fallceon	Fallceon quilleri	5	5	CG	"SW/10%, CN/90%"
Ephemeropte	Heptagenia	Heptagenia	5	4	SC	CN
Ephemeropte	Hexagenia	Hexagenia limbata	1	6	CG	BU
Ephemeropte	Isonychia	Isonychia	4	2	CF	SW/CN
Ephemeropte	Leucrocuta	Leucrocuta	6	1	SC	CN
Ephemeropte	Tricorythodes	Tricorythodes	57	4	CG	CN/SP
Haplotaxida	Oligochaeta	Tubificidae	1	10	CG	BU
Hemiptera	Naucoridae	Ambrysus mormon	1	3	PR	unk
Trichoptera	Cheumatopsyche	Cheumatopsyche	84	5	CF	CN
Trichoptera	Nectopsyche	Nectopsyche	11	2	SH	CM/SP/CN

Powder River, Site 5 @ Rough Creek. Targeted-Riffle EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Order	Taxa	Individuals	TolVal[1]	FFG[2]	Habit[3]
Diptera	Probezzia	1		PR	BU/SW
Diptera	Cryptochironomus	3	8	PR	BU/SP
Diptera	Polypedilum	18	6	SH	CN
Diptera	Hemerodromia	4	6	PR	SP
Diptera	Cricotopus	1	8	CG/SH	CN
Diptera	Simulium	25	5	CF	CN
Ephemeroptera	Traverella albertana	199	2	CF	CN
Ephemeroptera	Raptoheptagenia cruentata	7	2	PR	CN
Ephemeroptera	Cercobrachys	27		CG	"SP/75%, CM/90%"
Ephemeroptera	Fallceon quilleri	8	5	CG	"SW/10%, CN/90%"
Ephemeroptera	Heptagenia	1	4	SC	CN
Ephemeroptera	Isonychia	12	2	CF	SW/CN
Ephemeroptera	Leucrocuta	4	1	SC	CN
Ephemeroptera	Tricorythodes	13	4	CG	CN/SP
Haplotaxida	Tubificidae	1	10	CG	BU
Hemiptera	Ambrysus mormon	1	3	PR	unk
Odonata	Ophiogomphus severus	3	5	PR	unk
Trichoptera	Cheumatopsyche	87	5	CF	CN
Trichoptera	Hydropsyche morosa gr.	7	6	unk	CN
Trichoptera	Hydroptila	1	6	PH	CN
Trichoptera	Mayatrichia	1	1	SC	CN
Trichoptera	Nectopsyche	1	2	SH	CM/SP/CN
Trombidiformes	Sperchon	1		PR	unk

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[2] FFG designations MT DEQ has assigned. CG = collector-gatherer; CF = collector-filterer; SC= scraper; SH=shredder; PR=predator; OM=omnivore; UN=unknown.
[3]Habit is the general activity of the invertebrate. BU=Burrower, CM=Climber, SP=Sprawler, CN=Clinger, SW=Swimmer

Powder River, Site 6. Targeted-Riffle and Reach-wide EMAP. FFG=Functional Feeding Group, TolVal=DEQ Tolerance Value

Waterbody Name: Powder River@buttermilk
Station ID: YLBLMPW6T5
Collection Date: 7/12/2005

Order:	OTU name:	FinalID:	Individuals	Tol Val:	FFG:	Habit:
Coleoptera	Hydrobius	Hydrobius	1			
Diptera	Chironominae	Cryptochironomus	11	8	PR	BU/SP
Diptera	Chironominae	Cryptotendipes	12	6	PR	SP
Diptera	Chironominae	Micropsectra	1	4	CG	CN/SP
Diptera	Chironominae	Parachironomus	12	10	PR/CG/PA	SP
Diptera	Chironominae	Polypedilum	5	6	SH	CN
Diptera	Chironominae	Robackia	2	4	CG	unk
Diptera	Simuliidae	Simulium	11	5	CF	CN
Ephemeropte		Raptoheptagenia cruentata	2	2	PR	CN
Ephemeropte		Traverella albertana	98	2	CF	CN
Ephemeropte	Cercobrachys	Cercobrachys	11		CG	"SP/75%, CM/90%"
Ephemeropte	Heptagenia	Heptagenia	2	4	SC	CN
Ephemeropte	Isonychia	Isonychia	3	2	CF	SW/CN
Ephemeropte	Tricorythodes	Tricorythodes	6	4	CG	CN/SP
Haplotaxida	Oligochaeta	Tubificidae	2	10	CG	BU
Hemiptera	Naucoridae	Ambrysus mormon	2	3	PR	unk
Trichoptera	Brachycentrus	Brachycentrus occidentalis	1	2	CF	CN
Trichoptera	Cheumatopsyche	Cheumatopsyche	41	5	CF	CN
Trichoptera	Nectopsyche	Nectopsyche	1	2	SH	CM/SP/CN

Waterbody Name: Powder River@buttermilk Reach-wide EMAP
Station ID: YLBLMPW605

Order:	OTU name:	FinalID:	Individuals	Tol Val:	FFG:	Habit:
Coleoptera	Stenelmis	Stenelmis	2	5	SC/CG	"CN/50%, BU/50%"
Diptera	Chironominae	Cryptotendipes	1	6	PR	SP
Diptera	Chironominae	Micropsectra	5	4	CG	CN/SP
Diptera	Chironominae	Polypedilum	12	6	SH	CN
Diptera	Chironominae	Robackia	2	4	CG	unk
Diptera	Hemerodromia	Hemerodromia	2	6	PR	SP
Diptera	Simuliidae	Simulium	3	5	CF	CN
Ephemeropte		Neochoroterpes oklahoma	1		unk	CN/SP
Ephemeropte		Raptoheptagenia cruentata	3	2	PR	CN
Ephemeropte		Traverella albertana	42	2	CF	CN
Ephemeropte	Acerpenna	Acerpenna	15	4	SC	"SW/10%, CN/90%"
Ephemeropte	Cercobrachys	Cercobrachys	51		CG	"SP/75%, CM/90%"
Ephemeropte	Fallceon	Fallceon quilleri	5	5	CG	"SW/10%, CN/90%"
Ephemeropte	Heptagenia	Heptagenia	6	4	SC	CN
Ephemeropte	Hexagenia	Hexagenia limbata	4	6	CG	BU
Ephemeropte	Isonychia	Isonychia	3	2	CF	SW/CN
Ephemeropte	Pseudocloeon	Pseudocloeon	1	4	CG	"SW/10%, CN/90%"
Ephemeropte	Tricorythodes	Tricorythodes	10	4	CG	CN/SP
Hemiptera	Naucoridae	Ambrysus mormon	9	3	PR	unk
Odonata	Gomphidae	Stylurus	2	2	PR	unk
Plecoptera	Acroneuria	Acroneuria abnormis	1	2	PR	CN
Trichoptera	Cheumatopsyche	Cheumatopsyche	76	5	CF	CN
Trichoptera	Nectopsyche	Nectopsyche	9	2	SH	CM/SP/

Macroinvertebrate metrics and plains MMI calculations. T=Targeted-Riffle, and RW=Reach-Wide E MAP

StationID:	WaterbodyName:	CollDate:	TotalInd:	Plains Index	EPT Tax	EPT TaxScP	Tanypod Pct	Tanypod PctScP	Orth2 MidgPct	Orth2Midg PctScP	Predator Tax	Predator TaxScP	Filt CollPct	Filt CollPctScP
YLBLMPW105	Powder River 1@WY RW	11-Jul-05	295	**58.10**	14.00	100.00		0.00		100.00	5.00	55.56	77.29	34.94
YLBLMPW1T5	Powder River 1@WY T	11-Jul-05	597	**57.02**	10.72	76.54		0	12.5	87.5	4.56	50.7	54.27	70.35
YLBLMPW2T5	Powder River 2@drycreek T	11-Jul-05	613	**52.29**	10.25	73.24		0.00	28.57	71.43	4.28	47.54	54.98	69.27
YLBLMPW205	Powder River 2@drycreek RW	11-Jul-05	257	**49.17**	12.00	85.71		0.00	25.00	75.00	4.00	44.44	73.54	40.71
YLBLMPW3T5	Powder River3@Jenkins T	11-Jul-05	235	**60.16**	13.00	92.86		0.00		100.00	4.00	44.44	58.72	63.50
YLBLMPW305	Powder River3@Jenkins RW	11-Jul-05	234	**46.36**	10.00	71.43		0.00		100.00	2.00	22.22	75.21	38.13
YLBLMPW505	Powder River 5RW	12-Jul-05	246	**65.36**	12.00	85.71	1.63	16.26		100.00	6.00	66.67	62.20	58.16
YLBLMPW5T5	Powder River 5T	12-Jul-05	426	**60.50**	9.81	70.07		0.00	4.55	95.45	5.08	56.44	47.65	80.53
YLBLMPW6T5	Powder River6@buttermilk T	12-Jul-05	224	**49.00**	7.00	50.00		0.00		100.00	2.00	22.22	52.68	72.80
YLBLMPW605	Powder River6@buttermilk RW	12-Jul-05	265	**57.28**	11.00	78.57		0.00		100.00	5.00	55.56	66.04	52.25

Appendix E. Macroinvertebrate Protocol Comparisons with Percent Community Similarity and Taxa Similarity Per Site

Powder River @ Wyoming border		
TOTAL	**597**	**296**
CUMULATIVE TOTAL		**893**
Percent Community Similarity	47.98	
TAXA SIMILARITY	54.29	
Taxa	**Targeted_Riffle**	**Reach-Wide**
Acentrella turbida	1	1
Acerpenna	2	2
Acroneuria abnormis	2	1
Ambrysus mormon	5	4
Brachycentrus occidentalis	6	0
Caenis latipennis	0	1
Cercobrachys	3	6
Cheumatopsyche	124	130
Corixidae	0	1
Cricotopus	1	0
Dubiraphia	0	1
Fallceon quilleri	22	3
Helichus	2	0
Hemerodromia	5	6
Heptagenia	0	6
Hexagenia limbata	5	3
Hydropsyche confusa	4	0
Hydropsyche morosa grp	3	7
Isonychia	15	0
Ithytrichia	0	1
Leucrocuta	8	4
Lumbricina	0	1
Microcylloepus pusillus	7	10
Nectopsyche	0	7
Nematoda	0	2
Ophiogomphus severus	2	1
Polypedilum	7	18
Potthastia gaedii gr.	0	1
Raptoheptagenia cruentata	8	13
Simulium	78	5
Stenelmis	6	4
Stylurus intricatus	1	0
Traverella albertana	234	19
Tricorythodes	44	38
Tubificidae	2	0

Powder River @ Dry Creek Site 2

TOTAL	**613**	**257**
CUMULATIVE TOTAL		**870**
Percent Community Similarity	51.62	
TAXA SIMILARITY	41.67	
Taxa	**Targeted_Riffle**	**Reach-Wide**
Acentrella insignificans	0	1
Acentrella turbida	1	0
Anepeorus rusticus	0	2
Acroneuria abnormis	2	0
Ambrysus mormon	2	0
Brachycentrus occidentalis	1	0
Cercobrachys	3	41
Cheumatopsyche	105	30
Cricotopus bicinctus gr.	0	2
Cryptochironomus	0	3
Dubiraphia	0	1
Fallceon quilleri	12	9
Helichus	1	0
Hemerodromia	5	3
Heptagenia	0	3
Hexagenia limbata	12	4
Homoeoneuria alleni	0	2
Hydropsyche confusa	1	0
Hydropsyche morosa grp	16	16
Isonychia	8	1
Leucrocuta	4	4
Microcylloepus pusillus	3	0
Nectopsyche	0	4
Ophiogomphus severus	3	2
Orthocladius	1	0
Parakiefferiella	1	0
Polypedilum	5	1
Potamyia flava	2	0
Raptoheptagenia cruentata	14	9
Robackia	0	2
Simulium	125	21
Stenelmis	2	0
Stylurus intricatus	0	4
Traverella albertana	244	35
Tricorythodes	38	56
Tubificidae	2	1

Powder River Site #3-Jenkins Creek		
TOTAL	**449**	**347**
CUMULATIVE TOTAL		**796**
Percent Community Similarity	58.36	
TAXA SIMILARITY	70.00	
Taxa	**Targeted_Riffle**	**Reach-Wide**
Acerpenna	1	5
Ambrysus mormon	1	1
Cercobrachys	4	6
Cheumatopsyche	62	84
Choroterpes	3	0
Fallceon quilleri	1	5
Gyraulus	2	3
Hemerodromia	1	0
Heptagenia	2	5
Hexagenia limbata	1	1
Hydropsyche morosa grp	1	0
Isonychia	4	4
Leucrocuta	3	6
Microcylloepus pusillus	1	3
Nectopsyche	2	11
Polypedilum	15	7
Pseudocloeon	2	0
Raptoheptagenia cruentata	13	5
Robackia	1	0
Simulium	17	3
Sperchon	2	0
Stenelmis	2	2
Traverella albertana	72	25
Tricorythodes	21	57
Tubificidae	1	1
Sperchon	1	0
Thienemannimyia gr.	0	4
Traverella albertana	199	69
Tricorythodes	13	40
Tubificidae	1	0

Powder River Site #5-Rough Creek		
TOTAL	**425**	**246**
CUMULATIVE TOTAL		**671**
Percent Community Similarity	64.80	
TAXA SIMILARITY	40.00	
Taxa	**Targeted_Riffle**	**Reach-Wide**
Acerpenna	0	2
Acroneuria abnormis	0	1
Cercobrachys	27	20
Cheumatopsyche	87	29
Cricotopus	1	0
Cryptochironomus	3	0
Fallceon quilleri	8	5
Gomphus	0	1
Hemerodromia	4	0
Heptagenia	1	5
Hetaerina americana	0	1
Hexagenia limbata	0	2
Hydropsyche morosa grp	7	0
Hydroptila	1	0
Isonychia	12	5
Ithytrichia	0	2
Leucrocuta	4	2
Mayatrichia	1	0
Microcylloepus	0	1
Nectopsyche	1	6
Ophiogomphus severus	3	0
Polypedilum	18	33
Probezzia	1	1
Raptoheptagenia cruentata	7	0
Simulium	25	17
Sperchon	1	0
Thienemannimyia gr.	0	4
Traverella albertana	199	69
Tricorythodes	13	40
Tubificidae	1	0

Powder River Site #6-Buttermilk Creek

TOTAL	**224**	**265**
CUMULATIVE TOTAL		**489**
Percent Community Similarity	**50.94**	
TAXA SIMILARITY	**50.00**	
Taxa	**Targeted_Riffle**	**Reach-Wide**
Acerpenna	0	15
Acroneuria abnormis	0	1
Ambrysus mormon	2	9
Brachycentrus occidentalis	1	0
Cercobrachys	11	51
Cheumatopsyche	41	76
Cryptochironomus	11	0
Cryptotendipes	12	1
Fallceon quilleri	0	5
Hemerodromia	0	2
Heptagenia	2	6
Hexagenia limbata	0	4
Hydrobius	1	0
Isonychia	3	3
Micropsectra	1	5
Nectopsyche	1	9
Neochoroterpes oklahoma	0	1
Parachironomus	12	0
Polypedilum	5	12
Pseudocloeon	0	1
Raptoheptagenia cruentata	2	3
Robackia	2	2
Simulium	11	3
Stenelmis	0	2
Stylurus intricatus	0	2
Traverella albertana	98	42
Tricorythodes	6	10
Tubificidae	2	0

Appendix F. Fish and macroinvertebrate Community Group Descriptions

Group SPA #2- Medium Warmwater River Assemblage. Most of the medium to large warmwater river cyprinid species occur in this species assemblage (flathead chub, *Platygobio gracilis*; sand shiner, *Notropis stramineus*; plains minnow, *Hybognathus placitus;* western silvery minnow, *Hybognathus argyritis*), as well as the Catastomids: shorthead redhorse (*Moxostoma macrolepidotum*) and river carpsucker (*Carpiodes carpio*). Introduced species associated with this assemblage are the exotic carp (*Cyprinus carpio*), the plains killifish (Fundulus zebrinus), green sunfish (*Lepomis cyanellus*) and black bullhead (*Ameiurus melas*). This species assemblage occurs in many of the Medium Prairie Rivers of Montana, the free-flowing, undamned sections of the Missouri River, and is the integral assemblage of the Powder River, which includes the MT species of concern Sturgeon Chub. The channel catfish and stonecat could easily co-occur within SPA 1 or 2 if proper habitat requirements are met, such as deep, side channel pools and large structures for hiding (large cobbles, boulders or woody debris).

Large Prairie River Macroinvertebrate Community:
This community consists of members of the Large Prairie River and Filtering Collector Assemblage in the riffles, and the Large River Slow Current and Medium River Side-Channel Assemblages in the slow current and side channels areas, and the special sand-dwelling mayfly community group in the vast sandbar areas of the Powder River. The community indicator species are characterized by main channel riverine dragonfly species, *Stylurus and Ophiogomphus*, the mayflies- *Neochoroterpes oklahoma, Choroterpes, Camelobatidius, Fallceon quilleri, Acentrella insignificans, Ephoron album, Travarella albertana,* the caddisflies-*Icthythrichia, Psychomyia, Hydropsyche morosa* group, *Cheumatopsyche*, side- channel Hemiptera, the Corixidae, *Ambrysus mormon*-and the freshwater mussels- the fatmucket (*Lampsilus siliquiodea*) and the giant floater (*Pyganodon grandis*).

Group 37 **– Filtering-Collector Assemblage**-This moderately tolerant macroinvertebrate group is associated with warm-water medium and large rivers (4^{th}-7^{th} order) of low elevation (2000-3500 ft), low forest cover, high-linkages, high nutrient/turbidity and moderate gradient (slow-moderate current velocity) with stable→ shifting substrates. This community occurs in silt/sand/gravel substrates of large rivers (A001, A003, B006) or smaller (C007) degraded streams with sediment and nutrient problems. Two indicator taxa, *Simulium* and *Hydropsyche confusa,* can quickly colonize newly exposed substrates, so shifting sediments will not greatly disturb this community. Most of the indicator taxa are filterer-collectors or predators and can tolerate streams with higher agricultural and sediment influences than most other large stream/ river communities.
Stream and river examples: Frenchman Creek, Battle Creek, West Fork Poplar, Little Missouri, Powder River. Other indicator taxa: *Isonychia, Stylurus, Eukiefferella claripennis grp and Pseudocloeon*

Group SDM**- Large River, Sand-Dwelling Mayfly Assemblage-** This rare community type is rarely collected in traditional bioassessment samples due to their fast swimming abilities (i.e. net avoidance) and occurrence on extensive sandbars where typical samples are not taken. This community is associated with the largest class of rivers in the classification (5th –7th order) that are low elevation, low to moderate gradient with shifting sandbars and islands with side channels. River representatives include the Powder River and the lower Missouri and Yellowstone Rivers where suitable habitat exists. This large-river group has highly-specialized and globally rare indicator species: *Analetris eximia, Lachlania saskatchewanensis, Anepeorus rusticus,Ametropus neavei* and *Homoeoneuria alleni,* and are closely associated with species from the Large Prairie River Assemblage that occur in the riffle or other stable substrate areas. *Raptoheptegenia cruentata* is a member of this group but favors cobble riffles with an underlying sandy substrate.